THE BEAMA JOURNAL

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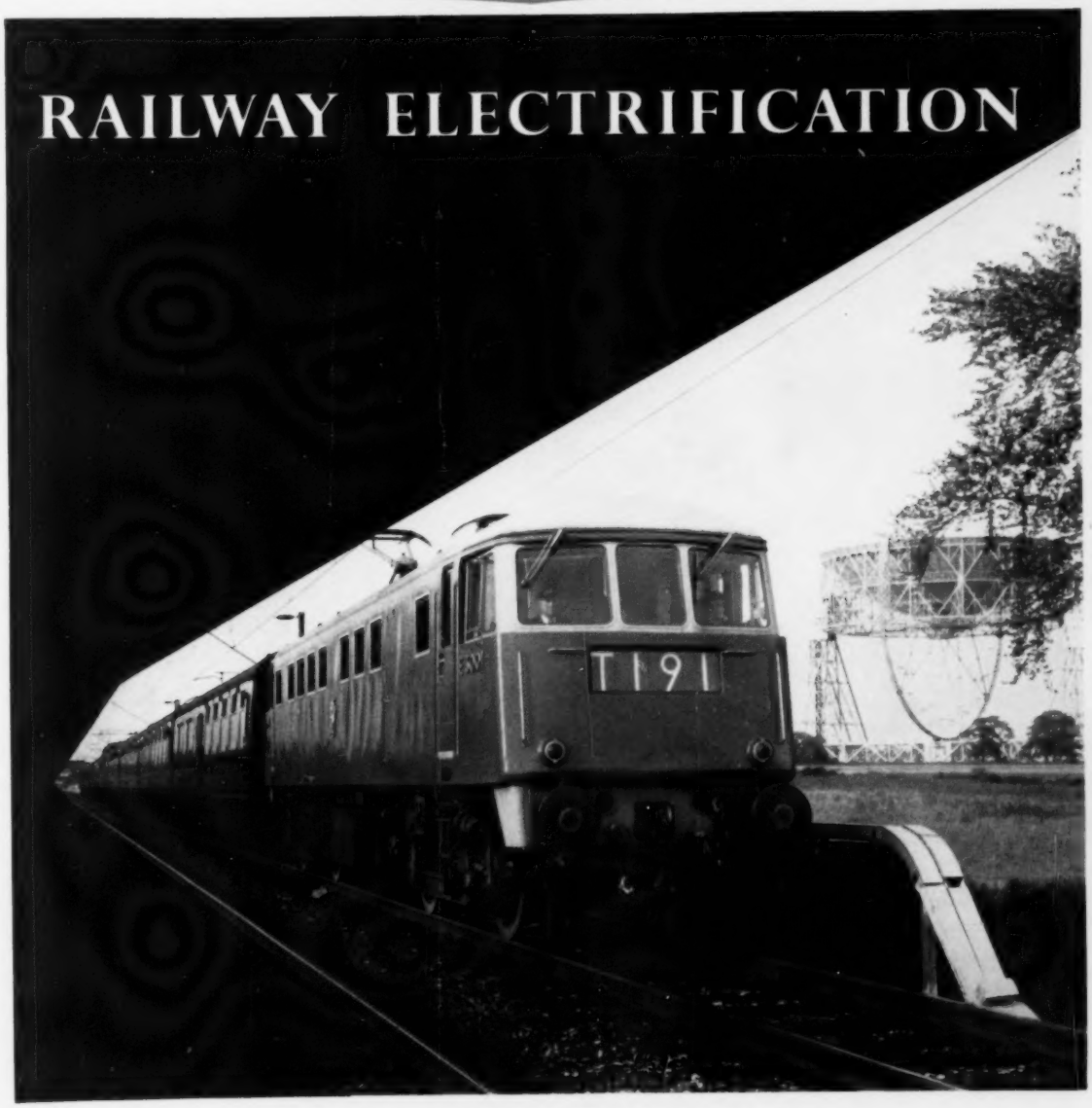
RAILWAY ELECTRIFICATION



A 25 kV ac electric train passing the Jodrell Bank radio telescope

A QUARTERLY REVIEW OF
BRITISH ELECTRICAL AND ALLIED ENGINEERING

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Cover Illustration. *This is a reproduction of the four-colour cover of a booklet specially produced by The BEAMA in connection with the recent British Railways Conference and Exhibition and describing the equipment and services which the British electric traction industry can provide. Readers who would like to have a copy are invited to write to us at the address below.*

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

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British Domestic Appliances at Next Year's Cologne Fair

Domestic electrical appliances from Britain are becoming an increasingly important factor in many countries overseas, and particularly in Europe. A survey of the European Common Market for electrical products recently carried out by The BEAMA estimates that over the period 1959-1963 the total value of domestic electrical equipment to be purchased or installed in the six Common Market countries will be of the order of £1 900 million.

About one-fifth of the electrical exports from Britain are bought by countries in Europe, the major markets being the Netherlands, Sweden and Western Germany. Domestic electrical appliances closely follow radio and electronic apparatus as leading commodities in this flow of trade.

This trend adds particular interest to the combined display of British domestic electrical products which will be staged at the International Household Goods and Hardware Fair in Cologne next February.

Promoted by The BEAMA in co-operation with the British Board of Trade, this collective exhibit will occupy three adjoining island stands in a prominent position in Hall II, near the main entrance and information centre of the Fair. On these stands visitors will be able to examine and discuss a wide and representative range of British electrical equipment for the home, including new models which will be making their first appearance at Cologne. Many of the appliances will have been specially designed and manufactured to meet the particular requirements and preferences of European buyers; all of them maintain the traditionally high standards of quality, reliability and fitness for purpose which have characterised British products ever since the first vacuum cleaner was developed in England in the early years of this century.

The importance of the Cologne Spring Fair is well-known to all our European readers. To all intending visitors to the Fair we would like, on behalf of the British electrical exhibitors, to extend a cordial welcome to their stands. An inspection will be well worth while, and a critical survey of the products displayed there will prove that Britain's wares can challenge comparison with those from any other country.

The Railway Conference and Exhibition

This outstandingly successful event has now passed into history—and to say that is no mere figure of speech, for if any occasion in the international calendar deserves to be called 'historic', this one surely does.

No conference and exhibition concerned solely with railway electrification and on such a scale has ever before been staged anywhere in the world, and for Britain to have done so—a country which, as Sir Brian Robertson pointed out, was later than others in electrifying its own railways—is convincing testimony to the lead which the railway industry has been able to establish in the engineering techniques and manufacturing skill and resources which were demonstrated to the delegates.

In fact, such an achievement stems directly from the many years of pioneering work in the field of d c electrification carried out by British engineers both in this country and overseas, to which has now been added the wide experience gained by British manufacturers and contractors in developing, manufacturing and installing 25 kV a c equipment for the British Railways Modernisation Plan and which is now available to any other country in the world.

The 42 papers read and discussed at the Conference and the principal exhibits by the 28 manufacturers at the Exhibition are reviewed in this special issue of THE BEAMA JOURNAL and form the major part of its contents. It will, we hope, provide a permanent souvenir and a convenient 'aide-mémoire' for the 160 or so delegates from overseas who were such welcome visitors.

Furthermore, this issue and the previous (August) issue dealing with other aspects of electric traction will convey to railway engineers all over the world a clear impression of a remarkable record of progress and achievement, and one which we hope (in the words of Mr D. H. Rooney, Chairman of the Electric Traction Section of The BEAMA) 'will go a long way towards convincing future customers that Britain can "deliver the goods" and that, given a fair specification and a fair deal, British prices can also be right'.

Generating at Supercritical Pressures

CONTRACTS worth about £15m are now being placed by the Central Electricity Generating Board for two 375 MW supercritical pressure generating units to be installed at Drakelow C power station near Burton-on-Trent in the Midlands. This will be the first central power station in Great Britain to have plant operating at supercritical pressures.

This significant development marks an important advance in the constant effort to achieve increased economies in electricity generation. The change from subcritical to supercritical pressures, coupled with an increase in the live steam temperature, is expected to give a station thermal efficiency in the region of 40 per cent, with the prospect of further increases in the future, whereas in the calendar year 1959, the three most efficient stations of the C E G B recorded average efficiencies of 33·88, 32·63 and 32·52 per cent respectively.

Consequential Advantages

There are also other advantages. Space is saved as the ratings increase, and the new 375 MW units—the largest single-shaft units yet ordered for the U K—will be hardly any larger than the 275 MW sets which are being supplied for other new C E G B stations.

Another problem arising from the increasing physical sizes of modern units is that of transporting the larger components to the site. However, the latest advances in design and the development of direct water and hydrogen cooling of the stator and rotor respectively have made it possible to increase alternator outputs while still keeping within the existing transport limitations.

One of the two new boilers will be built by Babcock & Wilcox Ltd and the other by International Combustion Ltd. The turboalternators will be built by Associated Electrical Industries Ltd (A E I) and the English Electric Co Ltd respectively. The supercritical pressure is 3 206·2 lb/in² absolute (2 321 kg/cm²) and at this pressure, water at a temperature of 705 deg F (371 deg C) passes directly into superheated steam without 'boiling' in the ordinary sense. The value of the latent heat of evaporation becomes zero, and as the densities of the steam and the water are practically identical there is no well-defined water-to-steam transition interface. Thus the boiler does not require a steam drum and is frequently known as a 'once-through' boiler.

The Babcock & Wilcox boiler will be a forced-flow 'once-through' type, fired with pulverised coal. It will supply 2 500 000 lb (1 134 000 kg) of steam an hour at a pressure of 3 650 lb/in² (2 566 kg/cm²) and a temperature of 1 110 deg F (599 deg C), a high proportion of the steam being returned to the boiler after partial expansion in the turbine for reheat to 1 055 deg F (568 deg C) at a pressure of 713 lb/in² (502 kg/cm²).

Fuel consumption will be about 150 tons (152 400 kg) of coal an hour fed to the boiler through large-capacity ball type pulverising mills developed by Babcock & Wilcox Ltd. These mills, which are of a new design, are suitable for dealing with the coal requirements of the largest boiler units now being constructed for central power stations. The coal will come from the East Midlands coalfield. The boiler will be manufactured mainly at the Renfrew and Dalmuir (Scotland) works of Babcock & Wilcox Ltd and erected on site by Babcock engineers. In its design and manufacture, the company has been able to draw upon considerable experience of supercritical pressure boiler plant in other Babcock installations.

Turboalternator Ratings

The rating of 375 MW is the highest for any single-shaft turboalternator in this country, and both A E I and English Electric have drawn on their long experience in building large subcritical units.

The specification of both units is similar; they will comprise a multi-cylinder 3 000 rev/min reheat turbine arranged as a tandem-compound unit coupled to a direct hydrogen- and water-cooled alternator with solid couplings between rotors.

Turbine steam conditions are: 3 500 lb/in² (2 460 kg/cm²) and 1 100 deg F (593 deg C) at the turbine stop valve, with reheat to the i p cylinder at 1 050 deg F (565·5 deg C). The vacuum at maximum and continuous rating is 28·7 in (729 mm) Hg. Eight-stage feed heating will provide a final feed water temperature of 505 deg F (262·8 deg C).

To meet the specified supercritical pressure and temperature requirements, double casings will be employed in the h p and i p cylinders.

The exhaust systems differ slightly between the A E I and the English Electric designs. The former will incorporate the A E I-Baumann multi-exhaust system in which a proportion of the steam leaving the penultimate blades is deflected to the exhaust casing. This system provides an exhaust area greater than that in simple-exhaust machines with the same last blade length and mean diameter, and consequently it will enable the last blade length to be limited to 29·5 in (75 cm) on a mean diameter of 83 in (211 cm). The tip speeds resulting from this arrangement will ensure that stresses will be at a reasonable level.

In the case of the English Electric unit, the quadruple-flow low-pressure cylinder is arranged in two double-flow low-pressure casings exhausting to one of the two condensers forming the twin condenser unit. In the case of the low-pressure cylinders ample area is provided in the four flows, as each employs a last blade of 36 in (91 cm) effective length on a mean diameter of 100 in (254 cm). This is similar to the 275 MW and 350 MW units for Blyth B and Drakelow C stations.

The alternators are of the direct-cooled type, employing water-cooled stator conductors and a hydrogen-cooled rotor, the rated gas pressure being 45 lb/in² (3·16 kg/cm²). The maximum continuous rating is 375 MW and the power factor 0·85.

The units are scheduled for commissioning in 1965.

Electrical Equipment in the R M S 'Windsor Castle'

THE 38 000 ton Union-Castle liner, R M S *Windsor Castle*, which made her maiden voyage on the South African mail service early this autumn, is the largest ship ever employed on this service, and is also the largest passenger liner ever built on Merseyside. She was built in the yards of Cammell, Laird & Co Ltd.

Several novel and interesting features of her equipment have been contributed by BEAMA member-firms, of which the following are brief details.

The *Windsor Castle*'s designers have made full use of electrification. To this end she is equipped with three main 1 500 kW generators for use at sea and three supplementary diesel-generator sets of 1 000 kW each for use while the ship is in port. The total output of 7 500 kW is six times as great as the power that could be generated in the *Carnarvon Castle*, the vessel which the new ship replaces.

The main generating equipment comprises three 1 500 kW 225 V d c generators driven through parallel-shaft speed-reducing gears by multi-stage high-efficiency turbines. The complete units were constructed by W. H. Allen Sons & Company Ltd, of Bedford.

The turbines are designed for an inlet steam pressure of 560 lb/in^2 (39 kg/cm^2) at 940 deg F (504 deg C) and exhaust to self-contained condensers at a vacuum of 29 inches (737 mm) Hg when using cooling water at 60 deg F (15·6 deg C). A leverless oil relay governor associated with four automatic valves on each set ensures that optimum efficiency is obtained at partial loads by controlling the nozzle area. Each self-contained condenser is complete with air ejector and motor-driven extraction and circulating water pumps. The turbines operate at a speed of 6 000 rev/min, geared down to the generator speed of 550 rev/min.

The Allen generators, which are wound for a 225 V supply, are of the enclosed ventilated type with a single pedestal bearing. The turbine end of the generator armature is solid-coupled to the low-speed shafts.

Cable needs were heavy, and nearly 200 miles (322 km) of cable were supplied by Crompton Parkinson Ltd—mainly V R 1 polychloroprene-sheathed fire-resisting types in single- and multicore construction.

Power is taken to a main switch board and then distributed to 16 master boards throughout the ship. These are divided into lighting, machinery, auxiliaries, refrigerating, deck and air-conditioning machinery, and galley and pantry equipment sections. Where necessary, the master boards supply section boards. Almost all the galley and pantry equipment is electrical.

Two Crompton Parkinson 25 to 40 V motor-generator sets, each of 1·6 kW, supply the ship's low power system, and run in conjunction with a 24 V battery.

The public rooms are illuminated by some 3 500 feet (1 067 m) of cold cathode fluorescent tubing supplied by the General Electric Co Ltd of England. De luxe warm white tubing, which has a colour rendering similar to that of tungsten lighting, has been used and most of it has been concealed in cornices.

In the first-class dining saloon there is an ambitious use of cornice lighting, including a gracefully curved main cornice housing four lines of tubing. Supplementary cornices running fore and aft house single and twin lines of tubes. The main cornice is suspended below the supplementary cornices so that, when illuminated, it appears to float in space.

During the day curtains under the forward part of the main cornice are drawn back to reveal a mural of Windsor Castle which is illuminated by two lines of 8 ft (2·44 m) hot cathode tubes. At night 5 ft (1·52 m) hot cathode tubes are used to light two smaller murals, one on each side of the main one.

Electrical loading of the cold cathode lighting in the first-class dining saloon alone is about 17 kW.

Other G E C equipment includes about 2 000 tungsten lighting fittings, including nearly 400 specially designed recessed ceiling fittings, and the low-voltage system incorporating a 50-line automatic telephone system for the ship's staff and services; a luminous call system which operates throughout the tourist accommodation; a fire alarm indicator on the bridge connected to 75 fire alarm buttons at strategic points all over the ship.

A view of the first-class dining saloon showing the mural of Windsor Castle referred to above

Engine room telegraphs, docking and steering telegraphs, rudder indicator, revolution indicators and torsion meters have been made and supplied by the Marine Department of A E I Telecommunications Division at Woolwich. The torsion meters give an instantaneous reading of the shaft horsepower developed at each of the ship's twin propeller shafts.

A feature of the engine room equipment is an automatic pneumatic control system designed by the A E I Instrumentation Division. This system is used to maintain pressure in the auxiliary exhaust steam range at a constant value, thus appreciably helping fuel economy.

Exhaust from the turbine-driven feed pumps discharges into the auxiliary range and is led to a large de-aerator feed heater which, for optimum efficiency, must be supplied with steam at constant pressure. The pressure is maintained within limits of ± 1 lb/in^2 (70 g/cm^2) either by dumping steam to the main condensers or by introducing l p turbine pass-out steam. If the latter is inadequate to maintain the desired exhaust pressure it is supplemented with h p desuperheated live steam.

The A E I exhaust control system operates on air signals in the range 3 to 15 lb/in^2 (211 to 1 055 g/cm^2). Pressure in the auxiliary exhaust range is taken from a sensing point to a pressure transmitter which converts it into a pneumatic signal. This signal is fed to a controller in which it is compared with the desired pressure. Any deviation causes the controller to produce an output signal proportional to the difference and this operates the valve positioners of either the reject or the supplementary control valves.

It is impossible for the condenser dump valves to be open at the same time as either of the supplementary valves, so the live steam cannot be rejected to the condenser. Additionally, interruption of the controller air supply causes the control valve to 'fail safe', so that the condenser dump valve closes, the l p turbine pass-out valve opens, and the h p desuperheated steam valve closes.

Systems of this type have been supplied for use in several of Britain's most modern naval vessels.

First A S E E Exhibition Dinner

A FORECAST of the size and scope of the 1961 Electrical Engineers Exhibition to be held in London next March was given at a dinner—the first of its kind—arranged recently by the organisers of the exhibition. This event, which was attended by more than 700 guests including High Commissioners, Ambassadors and Trade Counsellors from over 50 countries, was designed to provide an important contribution to Britain's export drive, and it also marked the beginning of a campaign to publicise next year's exhibition and to attract trade and technical visitors from all over the world.

The toast of 'The Electrical Industry' was proposed by Sir Eric Harrison, the High Commissioner for Australia, who said that he came from a mighty big country with a mighty big demand for electricity, ranking with the eight leading countries of the world as electricity consumers. He paid a tribute to the vigour of Britain and her role as a reservoir of scientific and technical knowledge on which the world has drawn heavily.

There was, however, an acute shortage of scientists and engineers, and he wondered if the West was matching Russia's capacity to produce them. 'This', he said, 'is a race we dare not lose'.

He emphasised the importance to Australia of the Snowy Mountain hydro-electric project which will have an ultimate capacity of 3 000 MW; one of the dams alone would impound 7½ times the amount of water in Sydney Harbour. 'Australia is a developing country presenting a challenging picture to engineers', he said.

Mr F. H. S. Brown, Deputy Chairman of the Central Electricity Generating Board, in replying to the toast described the Board as this country's largest buyer of capital equipment. He emphasised the value of the close co-operation and consultation which takes place between the Board and its suppliers in the electrical industry.

The toast of 'The 1961 Exhibition' was proposed by Mr R. F. Mathieson, Chairman of Electrical Engineers (A S E E) Exhibition Ltd, who said that all available space for the 1961 exhibition had been taken and visitors were assured of another comprehensive display by some 450 exhibitors covering every aspect of British electrical manufacture.

He also forecast that with the development of the Common Market and likely integration with the Outer Seven it is possible that premises may have to be found to provide suitable accommodation for a truly international display of electrical equipment to satisfy the needs of engineers at home and from overseas.

Mr W. J. Bird, Chairman of the BEAMA Domestic Appliances Board, deputised for Sir Leslie Gamage, President of the BEAMA, who was unfortunately ill.

He said that the organisers had built up the finest exhibition for the architect, the consultant, the works engineer and the contractor of electrical equipment which could ever have happened. He assured them of the exhibitors' continued support to make the Electrical Engineers Exhibition a great success.

In the course of his speech, Mr Bird said that the British domestic electrical appliances industry has a turnover of £250 to £300 million a year, and the aim is to make that figure £1 000 million a year. But he said that the industry had made a strong effort to impress upon the Government that stability is required instead of the present situation of changing restrictions. Given a stable home market the industry can settle down to the sort of planning, tooling and development which it needs and which will enable it to promote a virile export trade.

* * *

The Tenth A S E E Exhibition will be held at Earl's Court, London, from March 21 to 25, 1961.

English Electric House

THE new headquarters of the English Electric Group of Companies—technically the most modern office building in London and one of the first in which there is scientific control for main services—stands on the site of the old Gaiety Theatre in the Strand, which was for so many years the home of English musical comedy and became a tradition in the theatrical history of London during the first half of this century. The theatre suffered badly from bombing during the war and was demolished in 1957 after efforts had failed to raise the considerable sum of money needed to rebuild it as a theatre.

The new building adjoins Marconi House (which has hitherto been the English Electric headquarters) and this will now be known as the Marconi Wing of English Electric House. The main entrance façade is opposite the approach to Waterloo Bridge, and the two wings of the building extend 90 feet (27 m) along the Strand and 120 feet (37 m) along Aldwych, joining with the Marconi Wing to enclose a paved courtyard and garden containing a fountain which has as its centre piece the famous 'Angel', now restored and silvered, which formerly surmounted the Gaiety Theatre.

Symbolic Decorative Motifs

At each side of the main hall of English Electric House hang glowing tapestries representing 'Space' and 'Time'. They were designed by Hans Tisdall and specially woven for this purpose.

The casings of the lift shafts which can be seen from the hall and the mezzanine floor above are decorated by four abstract low-reliefs depicting Air, Water, Light and Tide. Each is 8 feet 6 inches (2·59 m) high, and has been chiselled by E. R. Bevan from 3 inch (76 mm) thick Nebrasina marble from designs also by Hans Tisdall.

The four passenger lifts in the main hall are each capable of carrying eight people at a speed of 500 feet (152 m) a minute. They operate as a group, are electronically controlled and can be programmed to suit the traffic demands as they change during the day. Each lift car is provided with an automatic weighing device which will weigh the passenger load so that the lift operates at near capacity. When this device has operated the lift will not stop in response to landing calls until the load has been reduced by passengers leaving the car.

The building is heated by two 1 200 kVA 11 kV electrode boilers (which are automatically controlled by time switches from one console) operating during off-peak periods. The boilers will operate under a static head of 140 feet (42·7 m) and will provide an output temperature of 270 deg F (132 deg C). The circuit breaker for each boiler is solenoid operated and the emergency lighting battery has been used to provide the d c supply for the circuit breaker solenoids.

Since the boilers will normally operate during the night time only, the heat then generated is stored in three thermal storage vessels. Together these contain 55 000 gallons (250 000 litres) of water at the generated temperature of 270 deg F (132 deg C).

The superheated water stored in the large polished aluminium vessels is used for heating the building by mixing with cooler water to achieve the various output temperatures required for differing purposes. There are eight separate distribution systems, including one for the hot water supply and one to the air heater batteries for air conditioning.

The space heating arrangements take the form of heating panels embedded in the structural ceilings generally, and in the floors of the entrance hall and exhibition hall. Each bay of the building has its own separate panels controlled by a thermostat and a control valve.

The air-conditioning system is provided by a number of plants serving separate sections of the building. One plant serves the Aldwych side and one the Strand side, in order to allow for the movement of the sun round the building and consequent changes in temperature. A third plant serves the exhibition hall which may have large or small audiences at different times. Separate plants for these areas give the most economical operation.

Fresh air for all the air-conditioning plants is drawn from a central area through a common intake chamber which serves the filtration sections of the individual plants. Two air filters are provided for each plant to

The main entrance of English Electric House, showing the two statues by Sir Charles Wheeler symbolising 'Speed' and 'Power'

remove the coarser and finer particles of dust respectively.

The primary filters are of the dry fabric type where the incoming air is passed through a blanket of glass fibre material. The type of filter used is a comparatively new development operating with two spools, the clean blanket being provided on one spool and wound across the air passage on to the other, the movement being controlled by a timing device. Warning devices are provided to indicate when the charged spool is exhausted, so that maintenance routines are simplified. The secondary filters are the electrostatic type in which the incoming air is passed through a positive field and the dust particles are consequently charged. A later section of the filter is charged to the opposite polarity and the particles are deposited.

From the filter sections the cleaned air is passed either to cooling batteries supplied with chilled water from the central refrigeration system to cool the air in summer, or to heater batteries supplied with hot water from the main boiler plant to warm the air in winter. In both cases the temperature can be pre-set. The fans distributing the conditioned air to the various systems are the cased centrifugal type of a recently developed pattern where the impeller blades are arranged in aerofoil shape, which increases efficiency and reduces noise level. From the main fans the conditioned air is distributed to the various sections of the building through insulated ducting rising in shafts behind the lifts. The high velocity principle has been adopted for the air distribution by high pressure fans specially treated to deaden sound.

An air distributing unit is fitted above the door in each room, or over the centre of the bay in a double room. At the room units, the primary supply of conditioned air is mixed with room air to provide an output double that of the primary quantity circulated. This effect is achieved by the introduction of a venturi within the distributing box which induces room air into the box before it is dispersed.

Air from each of the occupied rooms will be extracted into the corridor ceiling void and conveyed back to the basement plant chamber where it will be in part recirculated. This recirculation obviously makes for economy in heating and cooling power.

To provide chilled water for the cooling batteries, refrigerating plant with a total of 130 h p has been installed. This consists of two packaged units fitted in the sub-basement plant room working in conjunction with a cooling tower on the ninth floor.

The extract ventilation systems serving the basement garage, the board room suite and the internal lavatories are of the conventional type.

A substation for the electricity supply and plant for the heating system, the air conditioning and ventilation systems are housed in the lower basement.

All office areas are provided with semi-decorative fluorescent lighting fittings fixed close to the ceiling, which provide a lighting intensity in accordance with present-day requirements. The lift halls are illuminated by cold cathode tubing concealed in the plaster cornice.

A three-compartment underfloor duct system has been provided to carry the cables for telephones and light power supplies on all floors where there are offices. Access to the duct system is through floor boxes sited in most cases in the corridors.

A fire alarm system has been installed with pushes and alarm bells in the corridors and at the head of the staircase on all floors. Each floor is zoned to a central indicator panel, so that as soon as an alarm is given, the area from which the alarm came is recorded.

The cost of the electrical work was approximately £115 000 and included 1 200 lighting points, 950 13 A sockets, 400 impulse clocks, 60 fire alarm bells and pushes, 450 thermostats for control of heating, 90 000 yards (82 km) of cable and 800 telephone points.

The mechanical installation involved 11·5 miles (16·5 km) of water piping, 25 circulating pumps dealing with 200 000 gallons (910 000 litres) of water an hour, and 14 ventilating fans moving four million cubic feet (11 327 m^3) of air an hour.

A Unique Electricity Substation

THE particular interest attaching to the substation about to be described lies not in its technical equipment (which is quite standard), but in its entirely unusual exterior and surroundings.

It so happened that the South of Scotland Electricity Board found it necessary to instal a new substation in the Royal Burgh of Falkland, where is situated the ancient Castle of Falkland, whose history goes back to the 12th century. Load conditions dictated the siting of the new substation in West Port—a part of the Burgh famous for its 18th century charm.

Realising that (in the words of the Board's Deputy Chairman) 'a transformer sitting on a concrete slab and surrounded by an unclimbable iron fence' could not be called a thing of beauty, the Board's engineers looked for an alternative, and found it in an old cottage which was falling into ruins.

Locally known as the 'Reading Room', it is a typical two-storey double dwelling house dating from the early 18th century. In its original state it consisted of two rooms on each level, the upper floor being entered from an outside staircase—an architectural feature common to this part of Scotland. Like other small houses in Falkland, the cottage preserved a pleasing sense of the style of the period.

In restoring the main shell of the building for use as an electricity substation, the intermediate floor had to be removed, when the old timbers were found to be in a poor state and were therefore renewed. The decayed state of the masonry necessitated the application of lime harling, and great care was taken to secure the traditional texture.

The final result is an 18th century cottage serving most efficiently a 20th century purpose. A commemorative plaque on the wall records the story of the conversion, including the interesting fact that, according to local tradition, a family of 13 was once reared in the tiny upper flat of the cottage !

The Conference and Prospects for British Industry in Railway Electrification Overseas

D. H. Rooney, MA, AMIEE*

THE attention of overseas railways administrations has been focused on Great Britain by the British Railways Electrification Conference and Exhibition. Senior officials from more than 40 overseas railways joined their colleagues from British Railways and the traction industry at the Conference, at which papers were presented and discussed on all aspects of 25 kV 50 c/s electrification.

Concurrently with the Conference, an exhibition, organised jointly by The BEAMA and L A M A, was held at Battersea, at which all British manufacturers supplying equipment for the British Railways 25 kV electrification plan were represented. The delegates from railways overseas were thus enabled to visit the first co-ordinated 'shop-window' staged by British manufacturers, at which examples of all types of equipment for railway electrification were displayed.

The Exhibition revealed, for the first time in public, striking advances and developments in the use of materials and methods for overhead equipment, various types of cables, signalling and telecommunications, switchgear and rolling stock. The rapid advances made in the use of glass fibre may be exemplified: glass fibre used in the production of moulded components, laminates, tubes and rods gives extremely good mechanical and electrical properties, and when covered with modern plastics is replacing the use of conventional porcelain insulation in certain applications. Glass fibre has only been applied commercially in the railway electrification field for some five years, and the rapid development work on this unique material is resulting in its present application to section insulators, conductor terminations and cantilever assemblies, in all of which there is a substantial saving in first cost, weight, and consequent cost of erection.

Visits and Demonstrations

The two technical visits which were included in the Conference programme provided the British traction industry with further opportunities of showing its equipment to the delegates from overseas. On the newly-commissioned Manchester-Crewe electrification, the delegates travelled at speeds approaching 100 mile/h (161 km/h) in a train hauled by a 3 300 h p electric locomotive. Subsequently, the delegates inspected signalling installations, a display of electric rolling stock and a demonstration of various types of overhead equipment, together with purpose-made mechanical plant which a British contractor has developed for overhead equipment installation work. When visiting the electrification schemes in the Eastern Region, delegates viewed new power signal-boxes and a display of electric multiple unit trains. Many of the delegates saw a demonstration of the instrumentation of the system tests which the British Transport Commission, in collaboration with the industry and other organisations, has initiated to obtain performance data of all aspects of electric traction on a railway system.

In the weeks preceding and following the Conference, the majority of the delegates from overseas accepted invitations to visit railway equipment manufacturers' works over the length and breadth of Britain. There they had the opportunity of examining manufacturing processes, hearing about new developments and inspecting testing and research facilities. The various visits could have left the delegates in no doubt as to the ability of British manufacturers to supply well designed and efficient equipment for all systems of railway electrification.

The Electric Traction Industry

From the beginning of this century, the industry has grown rapidly and has achieved world-wide prestige and distinction for developments in the specialised electrical equipment of railways. These have covered the fields of motive power, power supply and distribution, signalling, telecommunications, and a wide variety of other applications. A high proportion of its business has been gained overseas and British manufacturers and contractors have successfully carried out major railway electrification schemes in the five Continents.

In the past, these schemes overseas and in Britain have normally been equipped for the low voltage (750, 1 500 or 3 000 V) d c system but in 1953, with the adaptation of the Lancaster-Morecambe-Heysham Line, British traction firms began to obtain practical experience

Carrying out overhead equipment construction work for Indian Railways 25 kV a c electrification programme. (Photo: B I C C)

* Chairman of the Electric Traction Section of The BEAMA

of the high voltage 50 c/s a c system. The first train in the world to operate with semiconductor rectifiers ran on this line.

With the decision by the British Transport Commission in 1955 to adopt as standard the 25 kV, 50 c/s system, the industry instituted considerable research and development in order to meet the new technical problems involved in applying this system to the complex conditions in Britain. The remarkable progress made by the industry, in collaboration with British railway engineers, was adequately demonstrated during the Conference.

Prospects Overseas

British manufacturers and contractors remain keenly interested in railway electrification projects in overseas countries, whether for d c or a c operation and with the system calculated to be most economic or technically advantageous to a particular railway. The present trend is perhaps towards a c operation at industrial frequency and British engineers are as well placed to advise on, and supply all equipment for, the a c system as they have been to undertake the electrification on the d c system of railways in many parts of the world. In short, British companies can supply and instal every item of equipment necessary to electrify a railway.

Under the auspices of the British Government, there has been set up the United Kingdom Railway Advisory Service (U K R A S)—a body which has been constituted with the object of providing an advisory service to overseas railway administrations on all aspects of railway management, modernisation, electrification etc. Its members include nominees from British Railways and the Ministry of Transport. Experts are therefore available to advise on all financial, operational and technical problems faced by overseas railways.

One of the standard permanent sub-stations supplied to the Netherlands Railways. (Photo: G E C)

While present developments in hydro-electric power in overseas countries can provide the right conditions for economic electric traction, it must not be overlooked that Britain will continue to face severe competition in this field, particularly from the Continent. Recent experience has proved that Britain is as advanced technically as are her competitors; in some aspects British developments are probably in the lead, but the principal criterion which will be adopted by potential customers will still be that of price. The variety of modern designs now flowing from British factories, the standardisation of components and methods, the development and use of new materials will all enhance Britain's prospects in a world-wide market which includes major schemes in Europe, Asia, Africa and South America.

A multiple unit train, one of many supplied to the Central Railways of Brazil. (Photo: A E I)

The experience gained by British manufacturers and contractors in developing, manufacturing and installing 25 kV a c equipment for British Railways electrification under the Modernisation Plan has enabled the traction industry to overhaul its competitors in the most modern forms of electric traction. But in the wide industry concerned with railway equipment and installations, Britain can only maintain and expand its trading position vis-à-vis competitors in an increasingly competitive field overseas provided there is a substantial and stable home market for railway traction equipment and installations. Our home market is an essential pre-requisite for developing, testing and demonstrating our equipment and for economic production.

The present and the immediate future is a most opportune time for overseas railway administrations to be approached, or approached again, not only as a natural follow-up after the London Conference and Exhibition but as a co-ordinated sales drive by British manufacturers able to supply a modern railway electrification system complete in all respects.

The Industry's Message

The Railway Electrification Conference will have confirmed British ability, skill and technology. It should have gone a long way towards convincing future customers that Britain can 'deliver the goods', and such customers will find that, given a fair specification and a fair deal, British prices can also be right. British manufacturers and contractors are indeed grateful to the British Transport Commission and the Regions for allowing them this opportunity of demonstrating to so many welcome visitors from overseas their progress in the railway electrification field.

The Railway Electrification Exhibition

THIS Exhibition, organised jointly by The British Electrical and Allied Manufacturers' Association and The Locomotive and Allied Manufacturers' Association, brought together the most comprehensive display of railway electrification equipment ever staged in this country. All the principal contractors and suppliers for the new B R electrification schemes were represented at the Exhibition, which was formally opened on the Monday afternoon by the Minister of Transport, the Rt Hon Ernest Marples, M P.

The survey of the exhibits which follows will, it is hoped, serve the dual purpose of reminding the visiting delegates of what they saw during their inspection, and of conveying to those who were unable to come to London some idea of the vast range of British equipment available to meet the requirements of railway engineers anywhere in the world.

It should be noted that many of the items in the Exhibition are also dealt with in the summaries of the Conference papers appearing on pages 153 to 171.

ASSOCIATED ELECTRICAL INDUSTRIES LTD

The Traction Division of Associated Electrical Industries Ltd was formed in 1959 by the integration of the Traction Departments of British Thomson-Houston Co Ltd and Metropolitan-Vickers Electrical Co Ltd, both of which have been manufacturing electric traction equipment since before the turn of the century.

Two complete A E I electric locomotives were shown—one of the E3001 type, of which there are 25, designed at the Rugby Works (formerly B T H) with mechanical parts sub-contracted to the Birmingham Railway Carriage and Wagon Co Ltd, and the other of the E3046 type, of which there are ten, designed at the Manchester Works (formerly M-V) with mechanical parts sub-contracted to Beyer Peacock & Co Ltd.

Alongside these locomotives, shown outdoors, there was a 3 300 h p electric locomotive of the E3056 type, one of 40 being built by British Railways with electrical equipment by A E I.

A Glasgow suburban multiple-unit electric motor coach was also on view. The mechanical parts for these are being built by the Pressed Steel Co Ltd at their Paisley Works, while all electric traction, heating and lighting equipment is supplied by A E I.

Indoors on the A E I stand were essential parts of electric locomotive equipment. Prominent among these were the rectifier exhibits: mercury-arc (multi- and single-anode), silicon and germanium rectifiers.

One exhibit was a six-anode pumpless steel-tank mercury-arc rectifier of the type used on the A E I 25 kV locomotives. Three of these rectifiers are installed on each locomotive.

There was also a single-anode pumpless mercury-arc rectifier tank, of the continuously excited type, as used on the Glasgow suburban multiple unit stock. Four of these rectifiers, specially designed for underframe mounting, are used on each train set.

A traction motor for a 3 300 h p locomotive was displayed, complete with a wheel and axle assembly incorporating the Alsthom type flexible drive, which reduces the unsprung weight of the locomotive to a minimum.

One of the main transformers as used on the Glasgow suburban multiple units was included among the exhibits. It has been specially designed for underframe mounting, and low tension tap changing is employed because of the difficulty in obtaining adequate clearance for the transition contactors which normally operate in air. This transformer is divided internally into two compartments. The core and windings are in one compartment and the two-way primary changeover switch is in the other.

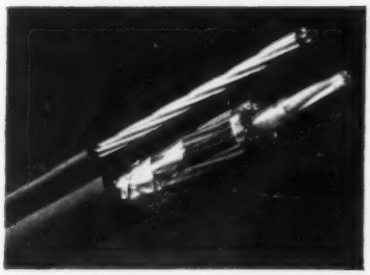
An interesting exhibit was an air-blast circuit-breaker as used on British Railways electric stock and this was shown working under simulated operating conditions.

Control gear and tap changing equipment were represented by a complete 1 t tap changing cam group from one of the Glasgow equipments and an 1 t locomotive camshaft tap changing group with motion gearbox, driving motor and notching relay.

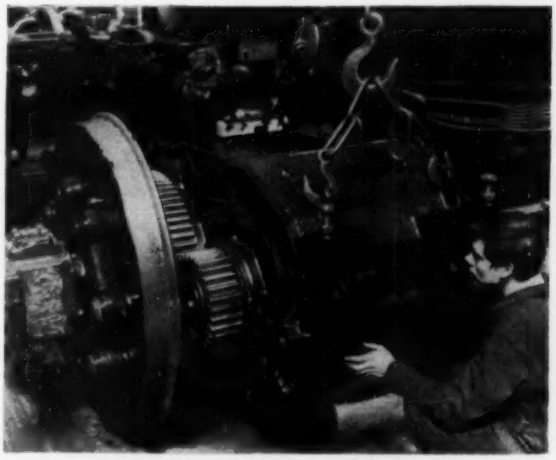
Other electric rolling stock parts on display included a controller, reverser, overload relay, contactor, potential transformer, relays and automatic power control panel.

For the transfer of electric power from the 132 kV national grid to the British Railway's feeder stations, the A E I Cable Division has developed a new type of feeder cable. This is a 25 kV concentric oil-filled cable which is being used extensively for the electrification of British Railways. Samples of both the lead-sheathed type and corrugated aluminium type of this cable were on view.

Concurrent with the design of the cable, joints and terminations were successfully developed and examples of sealing ends and straight-through joints were also shown.



The top picture shows a 'telescoped' sample of the A E I concentric oil-filled cable. Below is the self-supporting overhead telephone line with cable and suspension strand integrally sheathed in P V C



(Right) *An A E I 847 h p motor being fitted to an a c locomotive wheel and axle set*

Locomotives (Left, reading downwards): *Type A, 25 kV a c, 3 200 h p, built by British Railways, electrical equipment by A E I; Type A, 25 kV a c, 3 200 h p, built by A E I (Rugby) and the Birmingham Railway Carriage and Wagon Co Ltd; Type A, 25 kV a c, 3 000 h p, built by the English Electric Co Ltd; Type A, 675 V d c, 2 380 h p, equipment by English Electric Co Ltd; Type A, 25 kV a c, 3 310 h p, built by A E I (Manchester) and Beyer Peacock & Co Ltd*

Multiple unit stock (Right, reading downwards): *25 kV a c for the Manchester–Crewe section, built by British Railways with A E I equipment; 25 kV a c for the Glasgow suburban service, built by the Pressed Steel Co Ltd with A E I equipment; 25 kV a c for the Eastern Region, built by British Railways with G E C equipment and silicon rectifiers by Westinghouse Brake & Signal Co Ltd; 25 kV a c for the Eastern Region, built by British Railways with English Electric equipment*

H. J. BALDWIN & CO LTD

This company since its inception has been mainly concerned with the supply of clayware and precast concrete goods to a variety of users, but generally to those connected with the electrical industry.

Since the advent of new railway signalling techniques which have largely developed simultaneously with the electrification of British Railways, the firm has specialised in the manufacture of precast concrete cable troughing and fittings, and over the last ten years has supplied several hundred miles of troughing in various shapes and sizes.

The exhibit showed a representative selection of cable troughs, standard fittings and special purpose units, together with a small layout illustrating their application in practice. In addition, there were the well-known clay cable protection covers which have been widely used in this field.

THOMAS BOLTON & SONS LTD

This company's principal products are h c copper and 'Combarloy' (silver-copper) commutator bars and segments; h c copper strip for alternator and transformer windings etc; copper and cadmium-copper contact wire, and h c copper busbars.

This old-established firm was manufacturing copper and brass before the advent of steam locomotives; as suppliers of copper fire-box plates to British Railways and locomotive manufacturers in the U K and overseas, they played an important part in the development of steam locomotives.

Their high-conductivity copper products are now used extensively by the manufacturers of electric and diesel-electric locomotives in field coils and armature coils, for commutator bars of traction motors, generators and auxiliary machines, and for components of control equipment and for pantograph wearing strips.

THE B I C C GROUP

For nearly half a century the B I C C Group has played an important part in the electrification of railways in five continents of the world. In addition to providing overhead equipment for railway electrification, the Group manufactures and installs power cables and overhead transmission lines, telecommunication and signalling cables.

The exhibits on the stand were typical of the overhead equipment on the London Midland and Eastern Regions of British Railways and included all types of registration and supporting fittings, cantilevers, insulators and examples of the latest types of insulation. Other accessories included different types of section insulators, turnbuckles and line fittings with rail bonds and miscellaneous items.

Samples of the specially screened aluminium-sheathed telephone cables as installed on the Manchester-Crewe and Liverpool-Crewe electrification schemes were available, and an interesting demonstration illustrated the protection afforded by cable screening against the effects of interference from the traction system. Sections of cable troughing, trackside cabinets, joints and other cable accessories were also shown.

A length of the most recent concentric 25 kV oil-filled corrugated aluminium-sheathed track feeder cable was on display with a fully sectioned sealing end. Other exhibits included 25 kV twin concentric gas-filled cable and its straight-through joint; aluminium- and lead-sheathed cables; rubber and plastic insulated and lead-sheathed cables; rubber and plastic insulated and sheathed supply cables; train jumper cables and a complete assembly of a 25 kV pantograph cable with end bushing.

Signalling cables were exemplified by miniature P V C insulated and sheathed multicore cables; a 'Gloester' straight joint for multicore signalling cable; a glass fibre dome type inspection joint, and signal cabin wiring cables, together with all the relevant accessories.

At the entrance to the Exhibition site was a tower of the type designed to meet the B T C's need for low-level floodlighting. It was 50 ft (15·2 m) high and supported four A E I floodlights 55 ft (16·7 m) above ground. It was fabricated and galvanised by Painter Brothers Ltd of Hereford.

BRUCE PEEBLES & CO LTD

A display of photographs illustrated some of the transformers in sizes from 3 MVA to 10 MVA which have been supplied to the Eastern and Scottish Regions of British Railways for installation in substations supplying the overhead conductor systems at 25 and 6·25 kV.

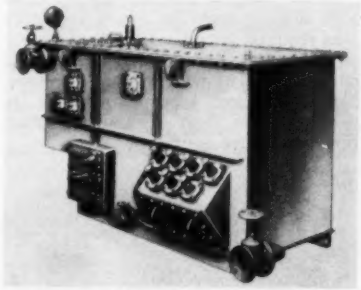
BRUSH ELECTRICAL ENGINEERING CO LTD

Some of the principal exhibits of this company's Traction Division were:

A 1 010 kVA 25/6·25 kV oil-cooled rectifier transformer for mounting below motor-coaches, and a high voltage change-over switch mounted in a tank. Also an air-break on-load tap changer for voltage control of rectifier transformers, and for field weakening of traction motors, designed for underframe mounting.

A silicon traction rectifier, type 6010, by the Westinghouse Brake and Signal Co Ltd. Nominal rating 700 volts, 1 000 amperes d c at 22·5 kV, 50 c/s, bridge connection. This has forced air cooling by external motor-driven fan.

The company is also building a number of electric locomotives for British Railways, and a representative exhibit was a 230 b h p traction motor, axle hung, nose suspension, self-ventilated, one hour rating, suitable for operation on rectified single-phase a c supply and incorporating Class B insulation to BS 173 : 1941.



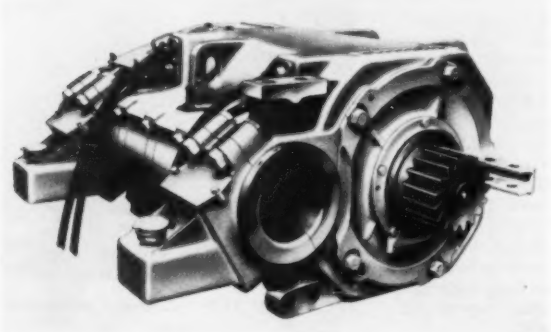
A Brush 1 010 kVA, 25/6·25 kV oil-cooled rectifier transformer for underframe mounting on M U stock

COMMUNICATION SYSTEMS LTD

This exhibit was principally devoted to the A T E selective ringing party line telephones which enable any way-station to be rung individually, even with the handset off the rest. These telephones, which were developed specifically to meet the requirements of the railway electrification programme, work on lines sectionalised by transformers. They employ a carrier frequency of 50 c/s which is amplitude-modulated at frequencies of one to 14 impulses a second to actuate the selective ringing device which consists of a galvanometer relay of the type used extensively in this country and abroad for ripple control over electricity distribution networks.

An all-electronic precision pulse source—the A T E crystal chronometer—was also shown. This has a time interval accuracy of the order of a few seconds per year, which is not affected by vibration or movement. It employs a crystal-controlled oscillator to generate a basic frequency which is fed to a series of binary dividers, the outputs of which are used to operate pulsing circuits at intervals to meet various requirements, including that for an extremely accurate timepiece.

Also exhibited was a cordless switchboard as used in association with A T E private automatic branch exchanges. Instead of the jacks, cords and plugs traditionally associated with telephone switchboards, this equipment has a neat row of press-buttons and keys for rapid handling of calls, together with many other time-saving facilities.



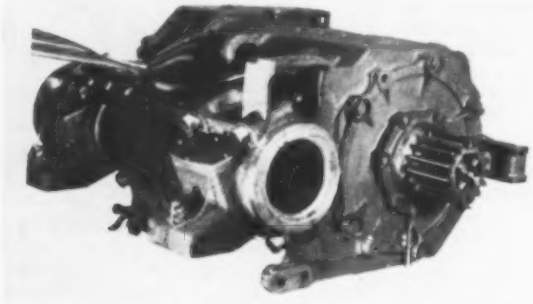
The Brush 230 h p axle-hung traction motor

CROMPTON PARKINSON LTD

The self-ventilated 1 500 V d c axle-suspended traction motor supplied by the company was specially displayed in dismantled form. It is suitable for operation on rectified single-phase a c supply at industrial frequency. Commutation is stated to be extremely satisfactory even with up to 30 per cent ripple.

The motor conforms with BS 173 in every respect. Class B insulation is employed throughout, the armature and field coils being fully bakelised. Field weakening is obtained by means of a tapped field. The insulation to earth is designed for a working voltage of 1 500 V d c so that the motor would be suitable for use on rectifier vehicles in dual operation on single-phase 50 c/s a c systems, as well as on 1 500 V d c systems.

Similar motors can be supplied either with larger outputs for forced ventilation —as required for main line locomotives— in conjunction with suitable flexible transmission, or having special high-speed construction and lower outputs for use with a cardan shaft drive to high-ratio, right-angle drive gearboxes.



A Crompton Parkinson 205 h p self-ventilated axle-hung traction motor

DOULTON INDUSTRIAL PORCELAINS LTD

The manufacture of traction insulators by this firm dates back some 60 years to the early days of the London Underground. Since then many thousands have been supplied for installations in the U K and overseas.

The exhibits comprised insulators of 8 000 lb, 15 000 lb and 30 000 lb (3 629 kg 6 804 kg and 13 600 kg) mechanical rating for both 25 kV and 6·25 kV duty, together with insulators for pantograph support and track switches. These have been developed jointly in consultation with engineers of the B T C and the British Insulated Callender's Construction Company Ltd, and in the course of tests on a special test gantry have proved their efficiency under conditions of severe pollution.

The material used for all these insulators is a fully vitrified high-grade siliceous porcelain, developed by Doulton for all high voltage applications.

ENFIELD-STANDARD POWER CABLES LTD

This company's display included samples of cable of all types applicable to railway electrification, together with sealing bell terminations and copper sleeve straight-through joints for 25 kV track feeder cables.

A notable feature of the stand was a cast iron line-side cabinet mounted on cast iron plinth, complete with terminal strips and links and with telecommunication cables terminated and connected.

Among the other exhibits were railbonds, moulded rubber plugs, sockets, glands and terminations for coach interconnector cables, oil immersion heater leads, and direction indicator cables, etc. Also shown were a grid suspension wiring system suitable for railway stations, locomotive sheds and marshalling yards; potheads for terminating dry core paper-insulated telecommunication cables, and an example of the firm's 'Unyte' wiring system for temporary lighting during tunnel maintenance, bridge building and similar operations.

THE ENGLISH ELECTRIC CO LTD

The English Electric Company can claim three-quarters of a century's experience in the manufacture of complete locomotives and equipment for electric railways.

In 1957 English Electric received orders for the electrical drive equipment for 112 motor coaches and 15 complete locomotives for the British Railways electrification scheme, and the first 25 kV a c multiple unit train was commissioned in 1958, followed by further trains in 1959.

Each four-car set comprises a driving trailer, motor coach, non-driving trailer and driving trailer. The motor coach carries four traction motors, two pairs of air-cooled single-anode steel-tank mercury-arc rectifiers, a tap changing transformer, reactors and a c and d c control gear. Automatic connections for either 25 kV or 6·25 kV operation are incorporated. All the electrical equipment is under-floor mounted.

The rectifier equipments for the 15 English Electric 3 000 h p electric locomotives differ from the motor-coach equipments in that eight water-cooled ignitron type mercury-arc rectifiers are mounted in an above-floor compartment.

Later orders placed with English Electric by the British Transport Commission include electrical drive equipment for a further 42 motor coaches. These equipments include silicon rectifiers.

In addition to equipment for 50 c/s electrification, all electric rolling stock for the Southern Region of British Railways, which operates the most intensive suburban service in the world, has been equipped with English Electric traction motors and control equipment since 1936.

THE EXPANDED METAL CO LTD

The Expanded Metal Company (Electrical Division), which incorporates The Cressall Manufacturing Co Ltd, specialises in the supply of resistors, rheostats and allied equipment.

Among the exhibits were:

A 25Ω track feed current limiting resistor for use in railway signalling circuits as supplied to the Westinghouse Brake & Signal Co; a set of tapping resistors for a c locomotives as supplied for the English Electric 25 kV a c locomotives; a set of motor field permanent divert resistors as supplied to the G E C for the conversion of existing d c Shenfield motor coach stock to a c operation; one frame of a 3-frame main starting resistor which is being used in the conversion of existing d c motor coach stock to a c operation; a display of Expamet resistor elements.

In addition the following exhibits made by The Cressall Manufacturing Co Ltd were displayed:

Wire wound rheostats, vitreous enamelled and open wound, used for instrument panel dimming; vitreous enamelled wire wound porcelain track feed resistors as supplied for Westinghouse 50 c/s signalling equipment; a band-type anode heater for rectifier pre-heating; railway cab heaters of 3- and 4-element types as supplied for 25 kV locomotives.

FERRANTI LTD

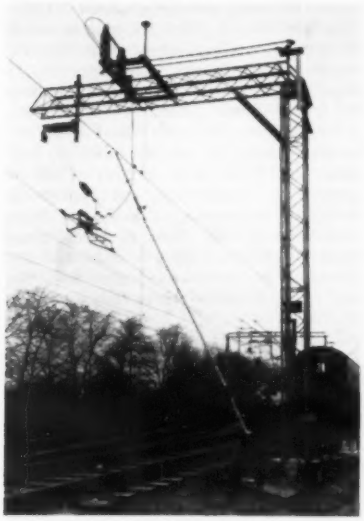
The first item of particular interest on this stand was the Ferranti railway type 'R' clip-on ammeter which has been specially designed for measuring alternating current in steel rails of the 95 lb (43 kg) bull head and 113 lb (51 kg) flat bottom types, as used on British Railways.

The main body of the instrument is housed in a black bakelite case with thumb-operated selector switch, but the limbs of the current transformer core are uninsulated.

Another specialised instrument was the Ferranti high voltage indicator, developed

The Ferranti clip-on ammeter referred to above

at the request of British Railways, in order that measurement of voltages on railway 25 kV a c overhead line could be carried out quickly, efficiently and safely. The indicator can distinguish between d c static, ordinary a c and induced voltages. Of the electrostatic type, the indicator has two ranges: 0 to 15 kV and 0 to 30 kV, the accuracy being approximately ±5 per cent of full scale. The complete equipment, *i e* testing rod, 2½ in (63·5 cm) dial electrostatic voltmeter and flexible earthing lead, can be easily dismantled and packed in a lightweight carrying case.

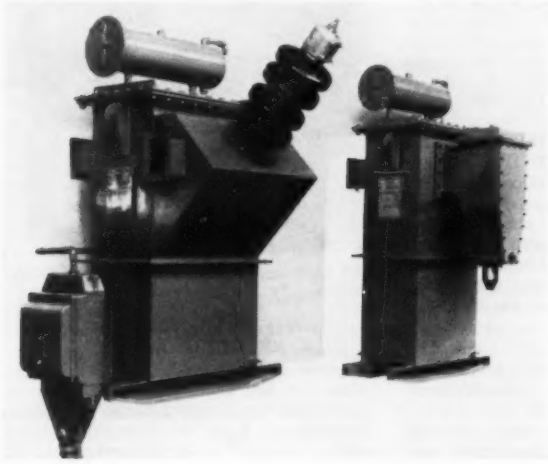


The Ferranti railway type h v indicator in use

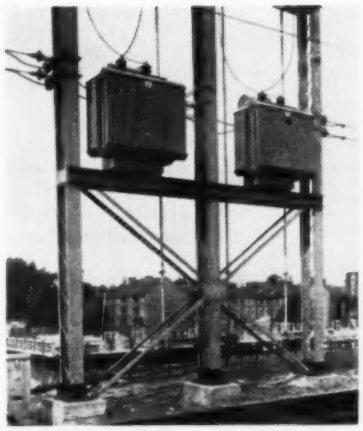
FOSTER TRANSFORMERS LTD

This stand featured various types of the company's specialised transformers and ancillary equipment, and the following brief descriptions indicate their particular applications.

Signalling transformer for auxiliary stand-by signalling and auxiliary equipment. This transformer would be switched on to the CEGB grid in the event of an emergency —for example, a failure of the railway supply.



Two representative Foster transformers for auxiliary stand-by signalling and auxiliary services



Two Fuller booster transformers for reducing interference. They are rated at 6·25 kV, 400 A

Booster transformers, for connection between the overhead line and the running rail to limit the electromagnetic induction disturbances to neighbouring telecommunication circuits.

Current and voltage transformers for 25 kV and 6 kV circuits, and a high accuracy current transformer for laboratory use.

Other equipment included high voltage oil test equipment for testing transformer and switchgear oil; high voltage test equipment for applying high voltage tests to electrical equipment; 2 000 A current injection test equipment for testing overload circuit-breaker coils etc; 5 kVA electronic constant voltage transformer, and a resin cast portable tool and lighting transformer.

FULLER ELECTRIC LTD

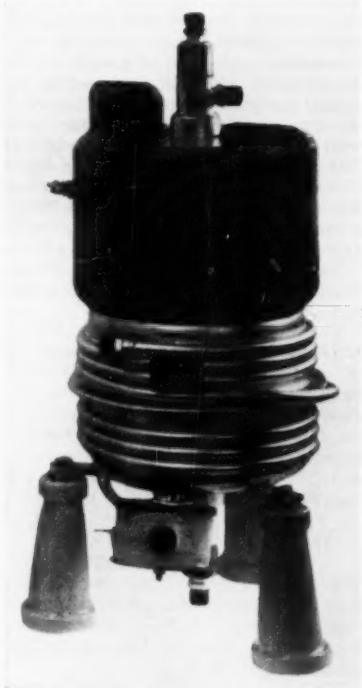
This company played a major part in the electrification of the former Southern Railway during the 1930's as main contractors for 33 kV a c switchgear and relay protection etc.

On the stand was to be seen a 25 kV air insulated switchgear unit with oil minimum circuit breaker as supplied to the Eastern Region of British Railways. The circuit breaker is rated at 800 A and has a breaking capacity of 300 MVA at 25 kV. Also shown were the core and windings of a 25 kV booster transformer representative of the 25 kV and 6·25 kV booster transformers developed in order to reduce telecommunications interference from traction return currents.

THE GENERAL ELECTRIC CO LTD

For upwards of 50 years this famous company has been a major supplier of electrical equipment for railways, and in 1922 supplied the first 6·6 kV 25 c/s a c equipments for the suburban systems of the former Southern Railway. Now, in connection with British Railways electrification, orders have so far been placed to cover the building of ten 3 300 h p locomotives for passenger and freight service, to run at speeds up to 100 miles/h, as well as electrical power equipments for 71 multiple unit trains.

In addition to rolling stock the company is supplying signalling equipment, train lighting and heating apparatus, and an associated company, Pirelli-General Cable Works Ltd, is supplying and installing overhead contact line equipment, feeder and communication cables. The exhibits gave a representative cross-section of the Group's activities.



A G E C 'Com-Pak' rectifier as used on the company's 25 kV a c locomotives

Power equipment for locomotives and multiple unit stock included traction motors, 'Com-Pak' rectifier equipments, transformers with automatic changeover switches and motor-driven tap changing switches, master controllers and a motor-generator blower set. The 'Com-Pak' mercury-arc rectifier attracted considerable interest; it has a particularly high power weight ratio and is capable of withstanding heavy overloads.

A G E C traction motor drive unit

Signalling equipment is supplied by The Siemens & General Electric Railway Signal Co Ltd, whose exhibits included artificial track circuits covering single rail d c and single and double rail a c; a d c searchlight signal with immunised windings and series protective chokes, and a phase-angle and relay energisation indicator for use in setting up a c track circuits.

Pirelli-General Cable Works Ltd showed a wide range of power and communication cables including 25 kV concentric oil-filled feeder cables, stainless steel sheathed self-supporting aerial cables, a low-loss communication cable spun to a catenary wire by an aerial cable spinning machine and special communication cable designed to prevent excessive induced voltages when used on 25 kV single-phase traction systems. The exhibits also included a double channel mast top complete with cantilever assembly, and photographs of overhead equipment erected by the company on the Glasgow suburban lines.

Various designs of apparatus for carriage heating, water heaters and lighting were included on the stand.

Fluorescent lighting operating through transistor-inverters from d c supplies was of particular interest. For locomotive-hauled stock a 40 watt fluorescent tube inverter unit operates on a 24 V supply. For the 25 kV multiple unit stock, a transistor-inverter has been developed for service on a 110 V supply and feeds four 40 W fluorescent tubes.

HACKBRIDGE AND HEWITTIC ELECTRIC CO LTD

The main exhibit on this stand was a 6.25 kV railway isolator consisting of two single pole units, one being actuated by a motor operated mechanism, and the other by hand.

The motor mechanism employs a series of springs to operate the isolator, and these are charged by means of a single phase 230 V driving motor. All three positions of the isolator are motorised. In addition, the isolators can be hand operated by means of a simple device which disconnects the motor and allows the springs to be charged by a cranked lever.

A large number of these isolators are in service on British Railways.

MICROCELL LTD

This exhibit demonstrated how an electronic 'supervisor' can be used for logging the performance of and controlling electrified railway systems. The datalogger can be arranged to have upper and lower pre-set controls available on every channel, and no output is effected by tape or printer until any one of the quantities being monitored wanders outside the prescribed set limits. Should all the readings return inside the limits, then the machine will automatically note the time and cease recording. Prediction that an event is about to occur is possible because limits can be set closer than the process under control demands.

The equipment can be supplied with 12, 24, 48 or 96 channels. The sampling rate is 160 milliseconds per channel; maximum decimal digit output rate: 25 per second; output code: international Teleprinter, or to order. Analogue to digital overall accuracy is better than ± 0.1 per cent. Input resistance: 1 MΩ.

THE MORGAN CRUCIBLE CO LTD

With nearly 50 years of crucible making already behind them by the turn of the century, the Morgan Crucible Co found in the invention of the carbon brush another outlet for their specialised knowledge of carbon and graphite.

Among the products manufactured by the Morgan Crucible Group, the following exhibits were directly concerned with railway electrification:

'Morganite' carbon brushes, brush holders and pantograph strips for traction equipment; metal, metal carbon and carbon contacts; carbon resistance rings and flange lubricators; 'Reservoil' oil retaining sintered bearings, and 'Foliac' switch plate and overhead conductor lubricants.

NALDER BROTHERS & THOMPSON LTD

This company showed a selection of electrical measuring instruments and circuit-breakers from their wide range and the following items were of special interest.

3½ in (89 mm) single and double moving coil edgewise instruments with illuminated dials for use on either d c supply or a self-contained rectifier pattern for use on a c supply.

These instruments are being supplied to the B T C for the new high voltage railway electrification.

A range of automatic earth proving supply points in standard patterns and totally enclosed patterns. They are suitable for use on single phase, three phase or d c supplies, and have been developed to safeguard the operators of portable and transportable electric tools.

Relays for connection in 83⅓ c/s systems to detect 50 c/s currents, as supplied for the electrification scheme on British Railways.

They are for use on an 83⅓ c/s track signalling system, where an excess leakage into the circuit of 50 c/s traction current could cause unreliable and spurious signal indications.

OTTERMILL SWITCHGEAR LTD

This exhibit took the form of a selection of cubicle and industrial switchboards, together with busbar trunking of all amperages and types and oil-circuit breakers and fuse switches.

A unit from each frame size of oil circuit-breakers from 100 A to 1 200 A with examples of drawout and non-drawout patterns was mounted on one display unit for close inspection, such units being available for wall, floor or switchboard mounting. Selected units of industrial and streamline fuse switches suitable for either wall or switchboard mounting were also shown.

There was also a comprehensive display of busbar trunking with ratings from 100 A to 600 A, together with accessories such as tapping boxes, cable units and bends, etc. This equipment is particularly suitable for workshops, machine shops, carriage washing sheds, etc.

This firm also manufactures cable trunking, underfloor ducting, and special multiple service trunking incorporating a combination of 100 A busbar trunking and cable channels suitable for laboratories, test stations etc.

An automatic earth proving switch by Nalder Bros & Thompson Ltd

A. REYROLLE & CO LTD

Reyrolle were showing a 25 kV single-phase air-blast circuit-breaker suitable for controlling the incoming supply to electric locomotives. It is of unit construction and is designed to be accommodated in

the roof-structure of the locomotive, It is composed of two principal parts; the circuit-breaker and its associated isolator which protrude above roof-level, and an air-receiver which, together with the circuit-breaker operating mechanism, is housed in the roof void.

The circuit-breaker has a making and breaking capacity rating of 250 MVA at 25 kV, and a normal-current rating of 400 A.

The blast-head of the circuit-breaker, which contains normally closed contacts, lies parallel to the locomotive roof and is supported on a vertical porcelain insulator which is also the blast-pipe between the air receiver and the circuit-breaker contacts. A porcelain-enclosed resistor is connected across the break and a vertically-mounted sequential isolator rotating through an angle of 70° is provided. The main contacts are readily accessible and are fitted with elkonite tips to minimise burning. Contacts for earthing both the circuit-breaker and the isolator are also provided.

The mechanism is actuated by a 100 V d c holding coil which controls the operation of the blast valve. In the event of power failure the circuit-breaker automatically opens and isolates.

The welded-steel air-receiver has a capacity of 1·5 cu ft (43 litres) (sufficient for two operations of the circuit-breaker); it has a design pressure of 130 lb/in² (9·1 kg/cm²), but normal working pressure is 100 lb/in² (7·0 kg/cm²). The air-supply to the receiver is drawn from the locomotive's main compressed air system.

Also shown was a 1 200 A 25 kV 250 MVA single-phase small-oil-volume circuit-breaker for use in trackside substations controlling the supply to the overhead catenaries.

Operation of the moving contact is by means of a simple bell-crank linkage driven from a rotating shaft coupled to a mechanism cubicle mounted alongside the circuit-breaker. The power-unit for closing the breaker is a motor-wound compression-spring, and opening is controlled by a kick-off spring charged when the breaker closes.

SOUTH WALES SWITCHGEAR LTD

One equipment on display, specially developed for electric railways, was the type SD6 6·25 kV single-phase air-insulated metal-enclosed switchgear unit. This unit is vertically isolated and fully interlocked throughout. It has a withdrawable truck-mounted circuit-breaker with integral raising and lowering mechanism. A single-phase 6·25 kV fuse-switch unit which lines up with this was also shown and this incorporates a 3-position single-phase oil switch.

Another exhibit was a type EO3 25 kV single-phase metal-enclosed unit. This comprises a fixed oil circuit-breaker which is isolated by single blade isolating switches operating in oil-filled busbar and feeder chambers.

The circuit-breaker is of standard double break design with a solenoid operating mechanism. The isolating switches are manually operated and are equipped with a complete interlocking system. Provision has been made for voltage transformers and current transformers.

A railway carriage shed showing the overhead trunking made by Ottermill Switchgear Ltd and referred to on the previous page

STANDARD TELEPHONES AND CABLES LTD

This well-known company is actively engaged in almost every aspect of railway telecommunications, and the stand afforded a comprehensive cross-section of its wide range of equipment and services.

A very comprehensive S T C remote control system is at present being installed on the Liverpool Street–Enfield–Bishops Stortford–Clacton–Southend a c electrification schemes, and a model of the S T C type of mosaic diagram was exhibited along with a typical outstation cubicle which houses transistorised voice-frequency telegraph equipment used for the transmission of coded signals between control station and outstations.

Railway signalling equipment was featured in a modern signalling control desk incorporating train describers. The control panel showed a typical track layout with all the controls and indications following a geographic pattern.

The description of all trains is shown in the appropriate place on the track diagram by means of miniature cathode ray tubes which in this case displayed a 4-digit train number.

Indications on the diagram show point setting, route locking, signal clearance and track occupation together with train description.

The exhibit also showed typical units of the signal post telephone system by means of which a train crew can call from any signal post to the signal cabin and thus provide a means of keeping traffic moving in emergency conditions.

To meet the world-wide demand for efficient telegraph systems and in particular for the best relaying facilities possible, S T C have designed and developed the 'Strad' automatic electronic telegraph relay system.

Within the Strad equipment, messages are handled at 83 000 words a minute. This high "cross-office" or handling speed is achieved by using electronic circuits throughout. Strad receives telegraph messages from a number of incoming circuits, temporarily stores them in a magnetic drum central message store, sorts all messages according to destination and then retransmits them to the appropriate outgoing circuits in order of priority and time of arrival.

S T C are supplying a wide range of cables to many regions of British Railways and have designed telecommunication supervisory cables which are specially screened to reduce the expected induced voltages from catenary wires at 25 and 6·25 kV, 50 c/s.

S T C also supply complete automatic exchanges and telephone equipment for railway signalling and telecommunications, and are now manufacturing and installing small-diameter coaxial cable telephone systems for British Railways. A repeater for this system was exhibited, the system being designed to provide up to 300 two-way telephone circuits over each pair of coaxial tubes in the cable.

The exclusive use of transistors in the repeater enables it to be housed in a buried case instead of requiring a building. Spaced 4 000 yards (366 m) apart along the route, these repeaters are fed with power along the cable itself.

Yet another exhibit was the S T C microwave equipment for multi-circuit telephony. Using radio channels in the 5 925 to 7 725 Mc/s band, this system provides four radio channels on a single route, each radio channel carrying up to 240 speech circuits.

The Stone-Faively pantograph used by British Railways

J. STONE AND CO (DEPTFORD) LTD

This stand featured the pantograph adopted by British Railways for their electrification schemes and supplied by this company. It is a development of that adopted by the French Railways for high speed duties after successful tests by the International Union of Railways (U I C). It is suitable for operation at track speeds

up to 100 mile/h (161 km/h) in both directions of travel and complies with the exacting requirements of lightweight catenary systems.

A distinctive feature of the pantograph is its sensitivity: it responds in service to a pressure differential measured in ounces. Its articulated members have low inertia, particularly the collector head. This is resiliently mounted and maintains contact under the most adverse conditions, for example when crossing stagger points and section isolators. The resilient mounting substantially reduces the effect of the hammering caused by these hard spots.

The base of the pantograph is a welded steel frame which can be supplied in various forms to suit the customer's fixing arrangements. The articulated members are of alloy steel tubing for strength, rigidity and light weight.

The pantograph has been designed for systems operating up to 25 kV but, with modified collector heads, is equally suitable for lower a c and d c voltages.

SWITCHGEAR & COWANS LTD

Two examples of this company's single-phase oil circuit-breakers and associated fuse units were on display. These were the type K11 oil circuit-breaker, 27·5 kV, 330 MVA and type B41 oil circuit-breaker, 6·9 kV, 165 MVA.

The K11 and B41 units are totally enclosed and oil-immersed, with fixed oil circuit-breakers, integral double isolation and earthing. Voltage transformers can be fitted to units thus supplying a voltage reference for the distance measuring feeder protection.

Type K11, 27·5 kV, 300 MVA oil circuit-breaker by Switchgear & Cowans Ltd

The oil circuit-breaker is electrically closed by means of a solenoid through a trip-free linkage. A patented self-compensating interrupter is fitted which maintains a consistently low level of arc energy over the interrupting range. High pressure faced contacts are fitted, the whole equipment therefore being suitable for repetitive duty. Relay panels are fitted to each unit.

The K11 and B41 fuse units are of similar style in appearance and construction to the oil circuit-breaker units, but in place of the circuit-breaker is fitted a high breaking-capacity cartridge fuse. Stress control spheres envelope the fuse clips. These units are used for the control and protection of standby transformers for signalling supply.

A Westinghouse selenium rectifier for charging the battery shown alongside and mounted on multiple unit stock

SWITCHGEAR AND EQUIPMENT LTD

The principal exhibits here were three-position track-sectioning isolators for overhead mounting together with power and hand operating mechanisms.

Both 6·25 kV and 25 kV forms of isolators were shown, with specifications as follows:

Voltage	*Rated Current*	*Short-time Current*
6·25 kV	1 800 A	24 kA for 1 sec.
6·25 kV	1 000 A	24 kA for 1 sec.
25 kV	600 A	18 kA for 3 sec.

The T S isolator is available either as a single unit, or with two isolators on a single base.

A flexible contact at the hinge pedestal is incorporated to give ample freedom allowing for the 90° blade movement.

The hand operating mechanism is arranged for padlocking and key-interlocking, and has a positive mid-way stop to prevent the isolator being moved accidentally from one extreme position to the other.

The power operating mechanism has a motor-charged hydraulically controlled driving spring which has ample power to operate the isolator in adverse track conditions of snow, ice, and soot deposits, but is controlled by the hydraulic damper to prevent over-speeding in free conditions.

The mechanism is powered by a geared electric motor; the supply can be any standard single-phase a c voltage, or from a battery, as specified. The mechanism incorporates limit switches and can be fitted with interlocking devices as required, and provision is made for emergency hand-operation.

WESTINGHOUSE BRAKE AND SIGNAL CO LTD

The Signal Division exhibited a model railway layout along which ran a model of the new British Railways type 'A' Bo-Bo 25 kV a c locomotive, the passage of which operated 4-aspect colour light signals in their correct sequence. Above the layout was a diagram of the track showing white route lights, red 'track occupied' lights and indications showing the signal aspects.

In front of the layout there were displayed various types of signalling equipment used on a c electrified lines.

Two sets of track circuits were shown, as follows:

The single rail Westatic style 'R' track circuit of the d c type which operates from an input of 110 V 50 c/s. An a c immune track relay is used and the whole equipment is unaffected by normal levels of 50 c/s voltages from traction sources appearing across the track. If under traction fault conditions there is a very high level of 50 c/s on the track which might cause a serious deterioration in train shunt, then the auxiliary relay associated with the feed set will release, disconnecting the feed equipment from the track and causing a safety side failure.

The Westatic 75 c/s equipment for double rail track circuits, which employs a static frequency converter for changing 110 V 50 c/s input into a 75 c/s output. At the relay end of the track circuit there is a frequency discriminator containing a filter and a rectifier. The d c output from the rectifier operates a standard track relay.

The Brake Division exhibited some of the more important components of the electropneumatic brake equipment supplied for British Railways a c multiple unit stock and components for the vacuum-controlled straight air brake equipment used on a c electric locomotives.

The e p brake controller is of the latest self-lapping design. Electrical and pneumatic isolation of the controller in non-operative driving positions is by a self-contained switch and pneumatic isolating valve which are operated when the controller handle is put into a special shut-down position, this being controlled by a small removable key.

The self-lapping straight driver's brake valve of greatly simplified design and the vacuum driver's brake valve with spherical valve and rubber seat were also shown. Both of these valves are supplied for the locomotive brake equipments and the designs are conspicuous by eliminating the metal valves previously employed.

The 'Pilotair' control valve was also shown. This is capable of a great diversity of applications, and it is used on the a c multiple unit stock to control the foot-operated horns.

The Rectifier Division exhibits included a Westalite traction equipment, one complete rack of silicon rectifiers forming part of a main traction rectifier equipment, and a selection of selenium and silicon rectifiers specially intended for traction service.

Silicon rectifier diodes of normal and reverse polarity, as used in the main traction rectifier, were shown, together with selenium rectifiers for traction operation.

Notes

New Canadian Distribution for British Welding Equipment

During a recent two-month trip to Canada, Mr R. W. Holden, Joint Managing Director of Holden & Hunt Ltd of Old Hill, Staffordshire and Chairman of the Resistance Welding Section of the BEAMA, concluded an agreement with F-H Welding Machines Ltd of Toronto for the sole distribution of H and H resistance welding machines throughout the Dominion of Canada.

H and H welding equipments have had C S A approval for 10 years and during this period have been exported to Canada in appreciable numbers. Under the new agreement, the Canadian company will hold a comprehensive range of H and H machines and spares and will undertake the servicing of all H and H machines sold in Canada.

This range of welding equipment from England will thus augment those produced by F-H Welding Machines Ltd since 1952.

British Industrialists Visit Western Australia

Under the leadership of J. O. Knowles, a director of the Metal Industries Group and the immediate past Chairman of The BEAMA Council, a party of British industrialists visited Western Australia in October last at the invitation of Western Australia's Minister for Industrial Development, the Hon C. W. Court.

The purpose of the visit was to explore at first hand the opportunities to establish new industrial capacity in the State and to stimulate general interest in the development of secondary industries there. The visit was part of a wider effort to develop the contribution of Western Australia to Australian trade generally and to strengthen the commercial links between Australia and the U K.

The other members of the party were D. J. W. Boag, managing director of Rockweld Ltd and a member of the BEAMA Council, who led the recent welding industry visit to the U S S R; M. H. M. Arnold, director of Bowmans Chemicals Ltd; R. T. Doncaster, managing director of Daniel Doncaster & Sons Ltd; John Glen, works director of Edward Macbean & Co Ltd; M. J. Noone, director of Whessoe Ltd; A. J. M. Price, managing director of Arthur Price & Co Ltd; J. R. Sharp, joint governing director of Lansing Bagnall Ltd, and F. L. Turnbull, general manager and director of Armstrong Whitworth (Metal Industries) Ltd.

At a Press conference before leaving the U K, Mr Knowles pointed out that Western Australia needed a variety of secondary industries built up by private enterprise to convert local materials and supplies into capital equipment and consumer goods for home and export trade.

Ten years ago, primary production formed 75 per cent of the State's total production; today it accounts for 55 per cent. In the same period the net value of Western Australian factory production had expanded from £A18 million to £A79 million annually.

During the visit, the party covered some 1 500 miles (2 414 km), chiefly in the south-west area of the State. This area contains the greater part of its population of 750 000 and includes Perth, the capital, and Fremantle, the major Australian port nearest to the growing Asian markets.

'The Electrician's Mate'

This is the title of a novel little booklet produced by British Insulated Callender's Cables Ltd, which has been specially designed and edited to give a comprehensive coverage of mineral-insulated cable work. It is intended primarily for the people who actually carry out the installations and has therefore been produced in a handy pocket size.

B I C C claim that there is no other comparable book of its kind in existence which deals with m i cable in such an explicit manner. It is written in an admirably direct and lucid style, and the whole subject is handled in a thoroughly practical manner. The illustrations (which are plentiful) are as clear and practical as the text.

Copies are available from any of the B I C C offices or from 21 Bloomsbury Street, London, WC1

The party leaving London Airport for Western Australia (see story in first column). From right to left, starting at the bottom row, the members of the party are J. O. Knowles, John Glen, J. R. Sharp. D. J. W. Boag, M. H. M. Arnold, M. J. Noone, R. T. Doncaster, A. J. M. Price, F. L. Turnbull

E R A Revises Its Committee Structure

The Electrical Research Association, which is one of the oldest of the research associations in the U K and which has, during the 40 years of its existence, given valuable service to the electrical industry, has recently reorganised its committee structure.

The reasons underlying this move were outlined by O. W. Humphreys, director for research and technical development of the General Electric Co Ltd and Chairman of the E R A Council. Briefly, it is designed to increase the Association's efficiency in research; to bring the selection of research programmes closely under the control of those who know the needs of the branches of industry directly concerned, and to secure the closest possible liaison between the staffs of the E R A and the specialists employed by its collaborating members.

The 20 Sectional Committees will now be replaced by six Divisional Committees, which have been given the following provisional titles: Insulation; Generating Plant; Power Supply Transformers; Switchgear etc; Power Supply Lines and Cables; Equipment — Light; Equipment — Heavy. Their primary responsibility will be to advise the Council on the work which the Association should undertake, covering both general and specialised researches in their respective fields.

Each Divisional Committee will appoint Research Advisory Committees largely drawn from the staffs of members of the Association who will use the results of the research or who will be able to provide information on such things as operating conditions and desired objectives. Scientists and engineers from the universities or elsewhere will also be invited to serve.

The Council believes that these measures will increase still further the E R A's very considerable contribution to the development of the electrical industry.

First E M I D E C Computer starts work

The first all-transistor computer to go into operation in the United Kingdom recently started working in the Nottingham office of Boots Pure Drug Co Ltd—the largest chain of retail chemists shops in the country. The computer—an E M I D E C 1100, manufactured and installed by E M I Electronics Ltd—is the largest single electronic data processing system so far at work in British business.

The E M I D E C's immediate task will be to replace the paperwork that goes on behind the scenes in connection with the ordering of goods from branches. It is now processing all orders for photographic equipment from 1 300 Boots shops, and will gradually take on other classes of goods until it covers all the 60 000 different lines stocked in Boots warehouses. It will keep a perpetual inventory of every one of these lines, showing how the stock stands at any given moment.

It is also expected to provide an opportunity of anticipating demand far more accurately than has ever been practicable before, making it possible, at least theoretically, to gear a whole organisation to a forecast of demand so that ordering,

warehousing, buying and production are all marshalled automatically to meet it.

The E M I D E C 1100, which has been ordered by leading commercial organisations and Government departments, is already in quantity production. Capable of performing nearly half a million calculations a minute, its data processing system was designed from the outset as a business machine, making it suitable for all types of clerical work from sales and payroll accounting to stock control and production planning. It also provides management with up-to-the-minute statistics in a fraction of the time taken by conventional methods.

Isolators for Scottish Supergrid

The illustration on this page shows a complete 275 kV isolator undergoing mechanical endurance tests in the compound at the works of Switchgear & Equipment Ltd at Banbury, Oxfordshire.

The first twelve of these isolators are due for delivery to the South of Scotland Electricity Board for the Strathaven substation in December this year. They are part of an order totalling £250,000 placed by the Board with Switchgear & Equipment and due for completion in September 1961.

The 275 kV isolator illustrated is powered by an electric/hydraulic mechanism and is fitted with hand-operated earthing blades of a type developed for this duty by the firm. The isolator is designed for erection as shown, or with the phases in tandem.

Modern Developments in Electrical Power Storage

In welcoming the guests at the 26th annual Press luncheon of the Chloride Electrical Storage Co Ltd, Mr Edward Powell, Director (Sales), referred to the company's two major markets: batteries for starting internal combustion engines of all kinds, and traction batteries. In the latter field the two principal outlets are factory trucks and electric road vehicles.

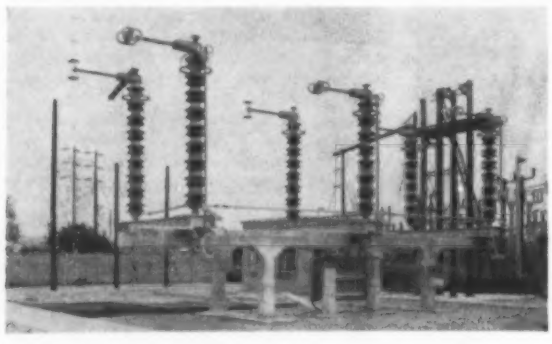
The use of battery electric trucks is steadily expanding, both in Britain and overseas, and he quoted official statistics which showed that of all the factory trucks produced in this country in 1957, 56 per cent had internal combustion engines and 44 per cent were battery-electric. In 1959 the position was reversed: 68 per cent battery-electric and 32 per cent with i c engines. While substantial improvements have been, and will continue to be, made in traction batteries, he claimed that there is no major market from which battery trucks are now excluded because of the limitations of the battery.

For road transport the battery electric vehicle has become firmly established as the ideal form of transport for relatively short journeys involving stops and starts, but its further development into the wide field now served by the i c engine is undoubtedly held back by the limitation of the battery.

Substantial improvements have been made in the power/weight ratio of traction batteries and ranges of 50 miles (80 km) and more at reasonable speeds are quite practicable. But once the battery is discharged, a relatively long time is still required to recharge from the mains. However, the other virtues of battery-electric traction—simplicity, economy, freedom from noise and fumes—are so compelling that the possibility of overcoming the present limitations imposed by the battery are of the greatest interest.

Mr Powell then referred briefly to new types of batteries (some of which are highly specialised and frequently of high intrinsic cost) and the so-called 'battery'—the fuel cell. The reason why the latter is of such interest in the battery world is that it is independent of the need to be re-charged in the ordinary sense; the so-called fuels providing the reactions which produce the current are fed into the cell from outside. He said that the completion of the development of the fuel cell is still a long way off (the most generally accepted period is of the order of five years), but it is possible that it may some day supply the means whereby electric traction independent of the mains will be considerably expanded.

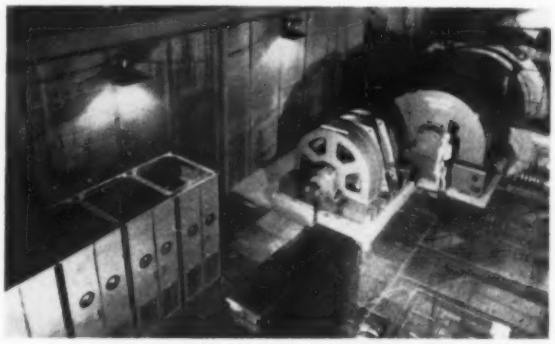
An interesting booklet dealing with these new developments is available from the company.



The 275 kV isolator by Switchgear & Equipment Ltd shown with phases in parallel

First African Mine Winder with Mercury Arc Conversion

In the 2b tertiary shaft at Venterspost, at a depth of 6 000 feet (1 829 m), Gold Fields of South Africa Ltd have commissioned the first d c mine winder in Africa supplied from a grid-controlled mercury arc converter. The complete electrical equipment has been supplied by Associated Electrical Industries Ltd, Heavy Plant Division.



The 1 200 h p winder in the Venterspost 2b tertiary shaft in South Africa. The mercury arc converter cubicles are on the left

The winder, which works in an ambient temperature of 85 deg F (29·4 deg C) (wet bulb) (90 deg F (32·2 deg C) (dry bulb), is driven by an A E I 1 200 h p 520 rev/min motor. Operating in a shaft 3 800 feet (1 158 m) long, inclined at an angle of 34° to the horizontal, its hourly output of ore is 185 tons (188 000 kg).

The first mine winder in Britain supplied by a mercury arc converter was installed by A E I in 1954. Since then, seven similar A E I winders have been installed—three of them of the multi-rope tower-mounted type.

In an underground winding house, such as that at Venterspost, a mercury arc converter has the following advantages:

power consumption is less than that with conventional equipment; standing losses are smaller; heat dissipation is less (with an a c winder, it would be almost twice as much); the winder and its associated equipment can be accommodated in a smaller space, and lighter foundations can be used; the installation is quieter than rotary equipment, and, since the conversion equipment is static, maintenance is reduced.

Electronic Forum for Industry Conference Report

The Report of the proceedings of the E F F I Conference on 'User Experience of Electronics in Industry' held in London concurrently with the I E A Exhibition last May, has now been printed for circulation to Conference delegates who attended from all over the world.

The 80-page report contains the 12 papers given by users of electronic equipment under the three main headings of electronics in data processing, factory applications, and instrumentation and control.

Application for copies should be made to the Electronic Forum for Industry, 11 Green Street, London, W1, enclosing a remittance for one guinea or its equivalent —frB 150, DM 12, frF 14, gulden 11, lire 1 850, frS 13.

Railway Electrification in Great Britain

THE AC ELECTRIFICATION CONFERENCE

S. B. Warder, MIMechE, MIEE*

IN a first article published in the August issue of THE BEAMA JOURNAL the early history of railway electrification in this country was traced up to the point where the first results of the British Transport Commission's decision to adopt 50 c/s traction at 25 kV were to be disclosed to a specially convened Conference. This Conference has now taken place and this second article now deals with the special features described in some of the papers read out and discussed there.

The Conference

As stated previously, the Conference was a joint venture with the manufacturing associations who have supplied the equipment, notably the British Electrical and Allied Manufacturers' Association; the Locomotive and Allied Manufacturers' Association; the Cable Makers' Association, and the Signalling Equipment Manufacturers.

Invitations went out to 126 railway administrations throughout the world and a highly satisfactory response resulted, the numbers attending being approximately as follows:

Foreign Railway Delegates	160
Miscellaneous Delegates	50
British Transport Commission Delegates	100
Industry Delegates	140

Any conference of a magnitude whereby 450 delegates have to be catered for, transported, entertained, and lectured in three or four different languages, demands a high order of organisation.

A permanent secretariat was the focal point for everything, and the success of all the functions reflects great credit on the co-operation of all concerned through the Chairman of the sub-committees and with the Conference Secretary (Mr Toneri) and his staff.

On the first day the proceedings were largely formal and were marked by the opening speeches and the presentation of a paper dealing with the reasons for the choice of the a c system. This was to set the scene and put the subsequent papers into perspective. The reasons for the choice of the system were dealt with in the previous article and here the arguments were summarised into those specific channels which concern so many countries faced with a similar choice.

The Exhibition

The official opening of the Exhibition took place in the afternoon, and the display at Battersea made history in bringing together a comprehensive collection of new designs of rolling stock and ancillary electrification equipment. This, the first of its kind in this country, was a great triumph for British engineering, since much was entirely new, employing techniques not available until recently.

Sir Brian Robertson, Chairman of the British Transport Commission, delivering the opening speech. On his right is Mr S. F. Steward, Director of The BEAMA

Not less exciting were the features and exhibits dealing with equipment of the future, following from the developments arising from the work done so far. This included the first British-built locomotive with silicon rectifier and rheostatic braking. There were also examples of the new form of PTFE glass fibre insulated supports for overhead wire arrangements which have an immense potential for the future.

The First Working Session

The first paper (No 2) to be presented to the Conference was a key paper, since it set out to describe the measures taken to prove the a c system by the most comprehensive test programme yet devised for electric traction. After all, if we believe the a c system to be superior to all others, evidence must be produced to justify that belief.

It was therefore as much for the benefit of the user and the manufacturer to have complete and precise data on which to judge the performance and efficiency of the system. The fact that no previous testing programme has been possible where the data has been automatically recorded during normal service operation has been due to the lack of the necessary instrumentation. Fortunately, new techniques have now come to the aid of the testing engineer and the variety of equipment provided makes a fascinating story.

Electric locomotives have to derive their electrical energy from a remote source, and they perform the function of a substation by transforming and converting the energy for use by the d c traction motors while changing their position relative to the power source. Movement can be at any speed up to 100 mile/h

* Chief Electrical Engineer, British Transport Commission

(161 km/h) and the liveliness of the vehicle and current collector adds its own complication to performance. There was also the influence on neighbouring signalling and telecommunication systems to be studied and safeguarded. In the present state of knowledge it is only too easy either to provide too many safeguards or too few, but intelligent deduction from measured results will permit all concerned to make wise decisions. The complexity of the exercise, which requires very detailed organisation and which has been a joint one with industry, has in itself broken new ground in collective testing where all the manufacturers who have supplied equipment have combined with the railway staff and other interested organisations like the C E G B and the Post Office to secure the desired performance results, which will be pooled for the benefit of all. The test programme described was therefore planned to produce the following:

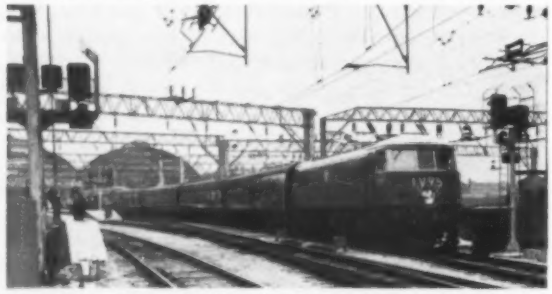
(a) the electrical performance of the traction system as a whole—including the power supply points,
(b) the performance of the principal items of equipment, individually and collectively,
(c) external effects.

Three papers were necessary to cover the work involved: Papers 12 and 13 dealing with the instrumentation and evaluation of results, and Paper 2 describing the purpose and the lessons derived to date from what must be the first system test programme ever devised for a traction system.

There followed an appreciation of the contribution of the Consulting Engineers who have been available to advise the Chief Electrical Engineer on any aspect where their experience could be usefully employed. There has been considerable scope for their employment, and not the least of their successes is a solution to the problem of operating 25 kV overhead wires through restricted bridges and tunnels in a clearance to the structure normally suitable only for 6·25 kV.

The Locomotives

No less than eight papers were presented dealing with locomotives—either collectively or in respect of certain special features of their design which were thought worthy of being brought to the notice of the Conference.



The inauguration of the Manchester-Crewe electrification. The train was hauled by locomotive E3040 built by the G E C and the North British Locomotive Co Ltd

The point was made that although there was no previous experience in this country of building a c locomotive equipments, the very large experience of making mercury arc rectifiers for the conversion of a c to d c could be used, as it had been decided for other reasons that d c traction motors should be employed. The contractors were permitted to offer either high or low voltage tap changing for speed control and a certain degree of licence was also allowed in regard to the mechanical design of bogies and frames suitable for an 80-ton (395 000 kg) locomotive on four axles.

From the number of alternative designs proposed a selection was made to enable four different variations to be built, and separate papers therefore were necessary to describe in detail the differing types. Since these papers are reviewed elsewhere in this issue no further comment is necessary here.

The last 40 of the first series of 100 locomotives, of which the mechanical parts are being built in railway workshops, will employ semi-conductor rectifiers instead of the previously intended mercury arc. This has been made possible by the rapid development in the use of germanium and silicon for power applications, and the resulting saving in weight has been utilised to incorporate rheostatic braking to secure considerable potential savings in the maintenance charges associated with brake shoe replacement.

High factors of adhesion, as expected, have been secured, and present thoughts incline to the view that axle-hung motors can perform adequately under British conditions and that full suspension with flexible drives is not essential; nor in fact is a single drive motor likely to be a worth-while development.

Multiple Unit Trains

British Railways requirements under the Modernisation Plan necessitated in the earlier stages a greater emphasis on suburban electrification than on main lines. Services in Glasgow and East Anglia ranked equally for completion with the first stage of main line between Manchester and Crewe which was to be the pilot scheme to prove the equipment. Together with the work in hand for d c electrification to the South and South-East coasts of the Southern Region, substantial quantities of multiple unit trains were required. In addition, the existing 1 500 V d c system from Liverpool Street to Chelmsford and Southend had to be converted.

The a c programme required some 400 train sets to be built, and again the opportunity was taken to employ the main manufacturers of this equipment for different schemes. The different types of train and equipment are covered by six papers. As in the case of the locomotives, later designs utilise semi-conductors, and their application for multiple unit working has been more rapid. It would seem that on all counts they are to be preferred, and will continue as a permanent feature. They occupy less space, can be mounted in any shape of container, require no ignition equipment and have no problems of starting in cold weather. Maintenance is negligible and they are no more expensive.

Considerable possibilities are being opened up by the rapid extension of silicon rectifiers to other fields, and we can confidently look forward to their further application as switching devices, resulting in a reduction in the size and number of current-breaking switches and contactors, and consequently in their associated problems.

Having presented this fairly wide and detailed review

of the amount and variety of equipment under trial in service conditions, Mr Broughall and Mr Cox gave some indication of the present thinking of the Commission in regard to the future. Design of mechanical parts has now crystallised as far as diesel locomotives are concerned, and the accumulated knowledge will assist in a similar situation for electric stock when the optimum layout consistent with cost and maintenance accessibility can be determined.

Riding is perhaps the most important question of all. A great deal has been learnt on this subject with the assistance of more scientific methods than have previously been available, and there is no reason to suppose that eventually the riding of multiple unit stock will not be equally as good as that of locomotive hauled stock. To this desired objective the continuously welded rail should also make a valuable contribution.

It is clear from the collective story provided by all these papers that in the rolling stock and locomotives now being provided for British Railways are the forerunners of a new era in railway history.

The Power Supply

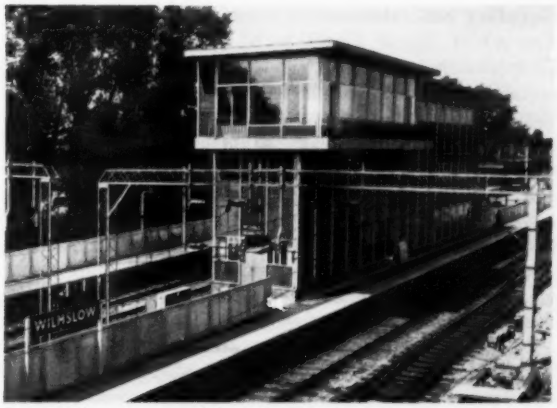
The remaining part of the first working session was devoted to a series of papers dealing with the power supply.

As is well known, the industrialisation and highly developed nature of the United Kingdom has led to a very strong and efficient power grid system. The steps taken to enable the railways to take a single phase supply at 20 to 30 mile (32 to 48 km) intervals are carefully documented and explained. It is shown that the out-of-balance caused by single phase loading is negligible and no embarrassment to the Central Electricity Generating Board. For the schemes so far authorised the total demand for power will amount to about 200 MW and consumption will be of the order of 950 million units a year.

Estimates of power demand based on the timetables for main line services between London, Manchester, Liverpool etc show an electrical load factor of the order of 70 per cent, and when compared with that usually resulting from suburban electrification, this indicates the scope for economy to be derived nationally as well as by the British Transport Commission itself.

Because of difficulties in obtaining electrical clearance in heavily built up areas where raising bridges was impracticable, it has been found desirable to reduce the voltage to the train. This could be done conveniently by a re-arrangement of the transformer windings, and therefore all locomotives and multiple unit power equipments have been made suitable for operation at either 25 or 6·25 kV. Because of the heavier currents involved, the 6·25 kV sections are restricted to the smallest area possible. Other methods such as track lowering, use of dead sections or of the insulating mat described in Paper No 14 are preferred as far as they are practicable.

Supporting papers on power supply dealt respectively with the effect of the load on the grid, the different types of switchgear that have been specially developed for single phase supplies, and the distance protection systems introduced for discriminative fault protection.



One of the new signal boxes erected in connection with the electrification schemes. This is at Wilmslow on the Manchester-Crewe line

Last but not least, a paper dealt fully with the remote control supervisory systems that have been provided for the different electrification schemes.

The Overhead Line Equipment and Associated Equipment

The second working session was concerned primarily with fixed equipment.

The significant feature of high voltage a c traction is that it uses smaller and lighter conductors, so permitting a reduction in the weight of the steel structures required to support them. This has produced an overall economy in spite of the large insulators, and to this has to be added the considerable savings to be derived from the omission of the railways' own lineside transmission system necessary for d c systems of traction.

A series of papers covered all aspects of the subject, and from them the complexity of detail which goes towards suspending a wire in a form from which a lightly balanced pantograph can collect current at speeds up to 100 mile/h (161 km/h) will be readily appreciated.

Perhaps the most interesting and exciting paper was one (No 33a) dealing with the developments which have taken place as a result of experience so far obtained. It gives some indication of the success achieved in the use of glass fibre covered with P T F E insulation, and foreshadows a great increase in the application of this technique in future schemes in Britain and overseas.

Research for A C Traction

A paper on the subject of research in electric traction is worthy of special mention in that this has been a field which has not received the support it has deserved, either by user or manufacturer.

Coupled with the Readership in Electric Traction now established at Imperial College, London, a separate research section has been created by the Commission to stimulate an all-out attack on those imponderables such as commutation and adhesion, in order to achieve still higher standards of technical and operating efficiency.

These are of course only two of many problems requiring attention, and the research section will see that proper attention is given in the appropriate quarter to all such matters, whether it be in industry, university or in the Commission's own research establishments.

Signalling and Telecommunication

The Chief Signal Engineer of the British Transport Commission presented the principal paper in this section, and it was supported by a series of papers on signalling and telecommunication equipment.

The Modernisation Plan had included a large measure of replacement of signalling and telecommunication equipment which has been outmoded by the introduction of modern motive power, higher speeds and closer headways. For the main trunk routes and densely operated suburban services colour light signalling was a necessity, and overhead open wire light current circuits were to be cabled as part of that programme.

In so far as a c traction was concerned, the problem for the signal engineer was to match his own modernisation programme with those additional requirements necessitated by the presence of 50 c/s traction current in the rails and on the contact system paralleling his own circuits.

A good deal of experimentation has had to be done on this subject and serious operational problems have been involved, particularly on the conversion of the Liverpool Street-Shenfield-Chelmsford and Southend lines, which were until recently working on 1 500 V d c. The signalling and track circuiting arrangements have been arranged for operating on either d c or a c traction, the solution adopted for this special case being to convert the track circuits to operate on an 83⅓ c/s supply. On other electrifications which are conversions from steam, d c track circuiting has been more generally employed.

The Interference Problem

While a good deal is known about the inductive effects of power lines on paralleling or adjacent circuits, little factual knowledge existed of the disturbance to be expected from the introduction of 25 kV single phase traction. Not only had railway circuits to be considered but also those of the British Post Office in close proximity to railway tracks.

There are two main ways of dealing with the problem: either to restrict the disturbance at source, *i e* at 25 kV, or to screen the light current cabled circuits. There is a third way: to arrange the light current circuits to withstand the disturbing effects with only light screening. This is known as the 'hot cable technique' and is used on carrier current cable telecommunication systems.

An interior view of the Wilmslow signal box shown externally on the previous page

It is not yet sufficiently developed for this particular application, and since the Post Office was unable to contemplate the problem of converting its d c ringing and dialling circuits which are a feature of British Post Office operation, it was decided as a general policy to suppress the interference at source.

The usual solution was to introduce booster transformers into the power circuits at intervals of about two miles (3·2 km). A separate return conductor is utilised to restrict the traction system loop and consequently its inductive effect. Alternatively, more closely spaced (about 1 mile (1·6 km) interval) booster transformers are used without return conductors.

A technical appreciation of the installations and the variations introduced experimentally were the subject of a special paper, together with contributions from authors from the British Post Office.

The system tests will be invaluable in providing accurate information on which to base decisions for the future.

Conclusion

It will be clear from the wealth of information included in all the papers produced for this Conference that collectively they represent the most complete and up-to-date record of this new form of traction at national frequency. The services are in their earliest stages and obviously much more experience has to be gained from which still more information will flow.

The Commission is satisfied that in adopting 50 c/s traction it has taken the right decision from the standpoint of British conditions, which are shown to be more onerous than are likely to be experienced elsewhere. It is therefore certain that this country can make an impressive contribution in the export field, which will come largely from the application of better equipment and the increasing knowledge arising from this expanding development.

The attendance of such a representative audience from all over the world testifies to the interest shown in the British solution to their problems.

Editor's Note. *In this article, Mr Warder has concisely and comprehensively surveyed the very wide field covered by the 42 papers read or discussed at the Conference.*

In the following pages, THE BEAMA JOURNAL *presents a specially written summary of the papers concerned with the electrical aspects of the Railway Modernisation Plan, amplifying many of the features mentioned by Mr Warder.*

For the convenience of our readers, the papers have been grouped under their respective subject headings and each subject presented as a self-contained section.

The full proceedings of the Conference, including all papers and discussions, will be published by the British Transport Commission towards the end of 1960 at the price of £5. Orders should be sent to the Publicity Officer, British Transport Commission, 222 Marylebone Road, London, NW1.

The Railway Conference: Locomotives

THE basis underlying the choice of types for the first 100 a c locomotives was discussed in a paper (No 3) 'The Locomotive' by E. S. Cox and G. G. Kibblewhite, of the British Transport Commission. As built, the fleet consists mainly of mixed traffic locomotives, referred to as type A. However, five have been built with a different gear ratio to enable early experience to be obtained with the bigger draw-bar pull such as will be ultimately required for working high-speed freight and mineral trains. These five are referred to as type B.

The specification did not stipulate a particular rating, but gave a number of duties. The following are considered to be those which determined design. The locomotive had to be able to haul a 475 ton (487 tonne) express passenger trailing load from Manchester to London with a balancing speed of 90 mile/h (145 km/h) on level tangent track and a maximum running speed of 100 mile/h (160 km/h). The average speed is 67 mile/h (108 km/h) with a stop of 1 minute, and 4 miles (6·44 km) at 15 mile/h (24 km/h) additional speed restrictions for track maintenance. In addition, the locomotive had to be capable of hauling a 950 ton (965 tonne) freight train between Manchester and London at an average speed of 42 mile/h (67·5 km/h) and a maximum speed of 55 mile/h (88·5 km/h). The locomotive would also have to work 500 ton (508 tonne) express freight trains (fully fitted) at a maximum speed of 60 mile/h (96·5 km/h) over this section.

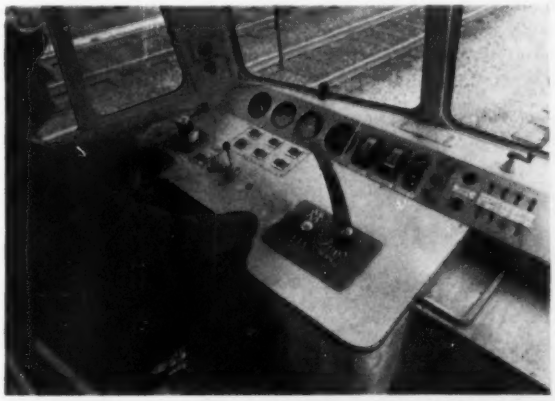
As regards low speed performance, the locomotive had to be capable of making three consecutive starts with the 950 ton train up to 20 mile/h (32 km/h) on a 1 in 100 gradient, and to be capable of working without damage to the equipment for 10 miles (16 km) at 10 mile/h (16 km/h) on any part of the route. This reflects the desire to ensure that no harm would come to the locomotives in the dense fog conditions that still occasionally prevail for several days. It can be regarded as a typically British requirement.

The type B locomotives were required to be capable of hauling a 1 250 ton (1 270 tonne) mineral or freight train between Manchester and London at an average speed of 42 mile/h (67·5 km/h) with a maximum speed of 55 mile/h (88·5 km/h) with the same conditions as specified for type A.

Roof equipment, drivers' controls, and certain railway mechanical equipment were standardised for all the locomotives. Stone-Faiveley pantographs are used. Two are fitted on each locomotive but under normal conditions only the trailing one collects the power. Carbon strips have been found successful, in spite of the heavy pollution of the contact wire by steam and diesel locomotives. The Brown-Boveri circuit breaker was adopted for the initial batch of locomotives, and an alternative of similar design recently produced by A E I has been incorporated in some of the later locomotives so that comparative performance can be assessed under service conditions.

The method of voltage changeover from 25 kV to 6·25 kV, necessary in situations with low clearance, has been standardised for both locomotives and multiple unit trains. Where such changes occur, neutral sections are introduced, consisting of three successive short sections of wire, insulated from earth but not energised. To avoid damage to the overhead wire and pantographs in the transition from live to neutral, automatic power control is used. This also enables multiple unit trains to negotiate neutral sections without the motormen shutting off.

Permanent magnet inductors are mounted on the sleeper ends outside the running rails, about 100 ft (30·5 m) before and after the neutral section. Each power equipment in the train carries a receiver, of the type used for the British Railways automatic warning system, which is mounted on the bogie and operated by the magnetic field of the inductors. The receiver is a polarised latched relay fitted with a reset coil. Contacts on the receiver armature operate a counting circuit formed of traction type relays; a contact of one of these relays interrupts the closing and holding circuits of the air-blast circuit breaker.



The locomotive controls have been standardised. This picture shows the driver's cab of the E3046 series

The four motor currents are individually indicated on two double ammeters. The scales are represented by coloured sectors, as the actual current value differs slightly between the various types of locomotive. The green zone is from zero to the approximate continuous rating, equivalent to 20 000 lb (9 100 kg) tractive effort. The next zone is amber and terminates at 50 000 lb (22 700 kg); the red zone extends above this value. Drivers are trained to accelerate the locomotives in the amber zone and to run them normally in the green zone.

Some indication of wheel slip is provided by these ammeters. Control of motor voltage by the transformer tap makes recovery from wheel slip by notching back simple and effective. In addition, a push button has been provided to give an anti-slip brake application equivalent to 5 000 lb (2 270 kg) braking effort.

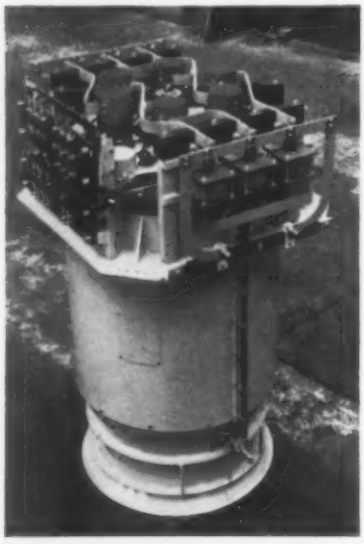
The different electrical designs adopted by the different manufacturers are outlined in the following sections.

A E I (Rugby) Locomotives (Paper No 15)

A E I (Rugby) Ltd received an order from the British Transport Commission for 25 complete 25 kV a c single-phase rectifier locomotives, and also for 40 sets of power equipments of the same rating for installation in mechanical parts to be built by British Railways. The 25 locomotives are equipped with pumpless steel tank mercury arc rectifiers, but the 40 sets of power equipments will use semiconductor rectifiers.

The locomotives produced by the company were described in a paper 'Locomotives: Nos E3001/23, E3301/2 (A E I Rugby)' by M. W. T. Rees, of Associated Electrical Industries Ltd. Locomotives E3001/23 are express passenger locomotives (type A), E3301/2 are mixed traffic locomotives (type B), and differ only in the traction motor gear ratio. Manufacture of mechanical parts was carried out by the Birmingham Railway Carriage and Wagon Co Ltd.

The main transformer primary winding is divided into four sections which are connected either in series or parallel to suit the 25 kV or 6·25 kV conditions. This arrangement only suits low tension tap changing and gives maximum economy of primary copper and protection against effect of line surges. Three separate windings make up the secondary of the transformer. Two windings, each giving half the rectifier phase voltage, are each connected in series with tappings at half rectifier phase voltage from a centre tapped auto-transformer. The auto-transformer is energised by the third winding of the secondary, at a voltage of approximately 2·5 kV.



A six-anode steel tank mercury arc rectifier used in the AEI (Rugby) locomotives

Transformer output is converted to direct current for the traction motors by three air-cooled six-anode pumpless steel tank mercury arc rectifiers, connected in parallel for bi-phase operation, so that each tank has three anodes carrying current in each half cycle. Reactors ensure equal sharing of the current between tanks and between individual anodes. The direct current output is fed to the four series traction motors by way of smoothing chokes. The motors are connected in parallel and separate motor contactors are not included, as motor overload protection operates on the high speed line breakers that are included to give rectifier back-fire protection.

The series d c traction motors are of six-pole design, with interpoles and lap wound armatures. Class H insulating materials are used and the continuous rating to B T C specification AC3, with the normal forced-air cooling rate of 3 000 cu ft/min (85 m³/min), is 975 V, 700 A, 847 s h p. One centrifugal fan serves each pair of motors.

English Electric Locomotives (Paper No 16)

The 15 locomotives built by the English Electric Group of Companies were described in a paper 'Locomotives: Nos E3024/35, E3303/5 (E E Co)' by W. G. Jowett and S. C. Lyon, of the English Electric Co Ltd. All 15 have identical equipment and mechanical parts except that 12 are geared for 100 mile/h (160 km/h) maximum service speed (type A), and three for 80 mile/h (129 km/h) only (type B).

Low voltage tap changing control is adopted for these locomotives. The supply enters the primary winding of the transformer through an air-blast circuit breaker and a supply changeover switch that connects the four equal sections of the primary in series for 25 kV or in parallel for 6.25 kV. Transfer from one transformer tapping to another is by closed circuit transition using resistance and reactance. Asymmetric tap changing is used, each tap change affecting all four motors equally, but above half voltage the symmetrical conditions only are available as running notches—to produce the best traction motor performance. Transformer tappings and selector contacts are used twice during acceleration by using the tapped secondary windings first alone, and then in series with equal untapped windings.

The tap changer is a cam-operated controller in two halves on a frame with the engine and gears arranged between the two camshafts. The main camshafts are operated through Geneva gears and the engine consists of three oscillating cylinders each carrying a piston and piston rod and arranged symmetrically around a crankshaft.

The locomotive contains two rectifier cubicles each containing four sealed ignitrons. The ignitrons are connected in two 3-wire bridge groups and the two traction motors of a bogie are permanently connected in series across a bridge. The centre points of the motor circuits are connected to the centre point of the transformer secondary and also to earth. Thus the motors are effectively in parallel. The ignitrons are water cooled units, 8 inches (20·4 cm) in diameter and 32 inches (81·5 cm) high.

Conventional 4-pole d c motors (type EE535A) are used. The motor frame is designed for mounting in the bogie frame and for use with the SLM Brown-Boveri resilient drive. Each motor has a rating of 837 V, 707 A mean when in full field at 750 s h p continuous, forced ventilation of 3 500 cu ft/min (99 m³/min) being used. The motors operate very satisfactorily with a ripple in the current of approximately 30 per cent at the continuous rating. Temperature rises of 150 deg C and 160 deg C are permissible in the armature and field respectively.

The main transformer has an additional winding for train heating and another for auxiliary supplies. The latter winding powers an Arno set, consisting of an Arno converter direct-coupled to a d c generator and a small tachometer alternator. The battery in the locomotive is used to run the Arno set up to near synchronous speed, using the generator as a motor. At the appropriate speed the tachometer alternator causes the single phase supply from the main transformer to be switched to the Arno converter and also opens the d c starting contactor. The Arno then drives the generator, which is automatically connected to the battery and floats under automatic carbon pile voltage regulation at 110 V. The oil and water pump motors, being small machines, are permanently connected to the Arno three-phase supply and run up as soon as the singie-phase supply is connected. The fan motors and blowers are connected to the Arno in sequence. This scheme permits the use of simple machines without commutators or capacitors, and gives constant speed to the a c connected auxiliaries. Hence the cooling apparatus is not dependent on line voltage.

The Arno converter is in essence a four-pole three-phase star-connected squirrel-cage induction motor, the stator windings being specially designed to enable it to run as a single-phase motor and to generate a three-phase output simultaneously. The converter can supply continuously a connected three-phase auxiliary load of 60 h p in addition to the load of the d c generator. The compressors and exhausters are d c machines.

G E C Locomotives (Paper No 17)

The ten type A locomotives in which the electrical equipment was produced by the General Electric Co Ltd of England and the mechanical equipment by the North British Locomotive Co Ltd were described in a paper: 'Locomotives: Nos E3036/45 (G E C)' by W. D. Morton, of the General Electric Co Ltd, and H. W. Scott, of the North British Locomotive Co Ltd. They differ from the others previously described in that the power circuits embody high voltage tapping.

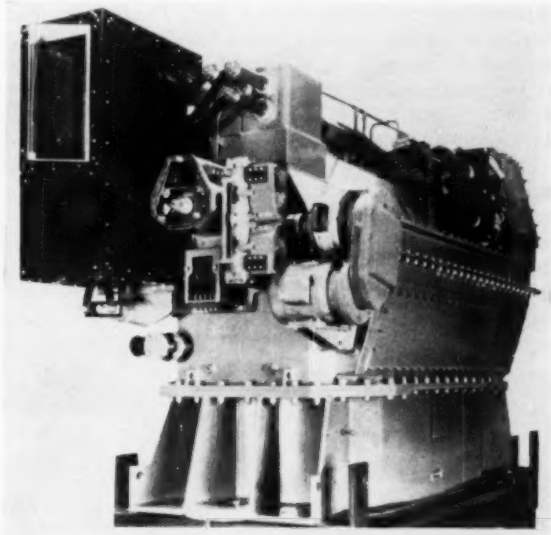
The main a c feed from the pantograph is taken via the air-blast circuit breaker and changeover switch to the regulating winding of the main transformer which is connected to earth at the four axlebox earth brushes through a negative link. The power circuits are based on effective parallel connection of the traction motors with high voltage tapping on half the regulating winding. The system reduces the current handled by the tap changer, simplifies voltage changeover, improves current-speed characteristics at low speeds, provides progressive tap change with simple resistance control, and with two rectifier transformer secondary windings dispenses with the need for anode chokes.

High voltage tapping contacts are incorporated in the main transformer tank under oil, with external load-breaking contactors for the transition currents. Geneva mechanisms ensure synchronisation of these contactors and the tapping contacts. The tap changer operates up to 12·5 kV with 20 voltage tappings. Intermediate notches are obtained by series resistance.

The regulated voltage supplies the main rectifier transformer primary via a ±5 per cent compensating tap. The two secondary windings feed 16 mercury arc water-cooled sealed-tank excitrons which form two bridge circuits; each supply two traction motors. The motor mid-points are connected to earth through an earth fault relay and to the mid-points of the secondary windings. Such an arrangement provides facilities for isolating a single motor or bogie pair of motors.

The duplex circuit arrangement allows the 16 rectifiers ('Compak' types, in which the cathode spot is anchored to the inner periphery of a circular cathode trough) to be mounted in two eight-tank frames with their associated excitation equipment. Two cooling circuits are used in each frame—one for the tanks and cathodes, the other for the anodes. The rectifiers are excited in groups of four cylinders to enable any traction motor to be isolated; each group has a common 240 V transformer with individual 50 V secondaries for each cylinder. In this application, each rectifier is rated at 250 A average d c, 850 V.

The traction motors are six-pole series motors, lap wound, force ventilated, with Class H insulation for all windings. Each frame is fabricated and fitted with an internal laminated ring bridging between the laminated main poles and interpoles. Compensating windings carrying the full armature current are accommodated in the main pole faces. The full field continuous rating is 725 A, 850 V, the armature peripheral speed at 100 mile/h (160 km/h) being 12 000 ft/min (3 650 m/min) with half-worn wheels.



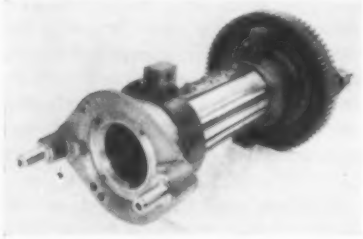
The tap-change unit of the G E C 25 kV a c locomotive, E3036 series

A E I (Manchester) Locomotives (Paper No 18)

The ten type A locomotives produced by A E I (Manchester) Ltd (electrical equipment) and Beyer, Peacock and Co Ltd (mechanical parts) were described in a paper 'Locomotives: Nos E3046/55 (A E I Manchester)' by G. R. Higgs, of Associated Electrical Industries Ltd. Like the Rugby division's locomotives, these use multi-anode air-cooled steel tank mercury arc rectifiers developed from industrial designs. However, they have

a different body design for the locomotive and use high voltage tap changing.

Variation of the main transformer secondary voltage is achieved by high tension tap changing on an auto-transformer. The auto-transformer has 38 taps to which the tap changer is connected, and three of these are also used to provide locomotive auxiliaries and train heating. The tap changer is driven by an electric motor through a Geneva wheel mechanism and comprises two sliding contacts operated by pre-stretched chains. These contacts move along the surface of a vertical row of studs, which in turn connect to the 38 taps on the auto-transformer. The tap changer, together with the carbon type transition resistor, is housed in a rectangular vertical casing which forms an extension to the main transformer tank and is oil-filled. The two current-rupturing air break switches that carry out the actual transition from one tap to the next are mounted on insulators on the transformer tank.



(Left) *A partly dismantled quill drive as used on all A E I locomotives,*
(Right) *A bogie of the A E I (Manchester) E3046 series*

Each of the three rectifiers has its anodes grouped to form, in effect, a two-anode tank, and therefore the bi-phase system of connections is used. The four traction motors in parallel connection are fed from the cathode connection common to all three rectifiers and through a common smoothing reactor from the main transformer secondary mid-point. The rectifiers and motors are the same as those used in the A E I (Rugby) locomotives.

Taps at 240 V and 800 V in the auto-transformer provide a supply for the locomotive auxiliaries and for train heating respectively. The locomotive auxiliaries fall into two categories. One comprises the majority of the auxiliary machines and all heating circuits, which are supplied at 240 V single phase a c from the auto-transformer tap. The other includes the main and auxiliary compressors, the exhauster, all locomotive lighting circuits, and the battery. The last is supplied at 110 V d c from a germanium rectifier bridge, which in turn is fed from the 240 V a c supply by way of a 240/137 V 16 kVA stepdown transformer.

The A E I 25 kV airblast breakers supplied to British Railways for locomotives and MU stock

British Railways/A E I Locomotives (Paper No 19)

The 40 type A locomotives whose mechanical parts were designed and built by the British Transport Commission were described in a paper 'Locomotives: Nos E3056/95 (B R/A E I Rugby)' by G. G. Kibblewhite, of the British Transport Commission, and F. Horne, of British Railways. The electrical equipment designed by A E I (Rugby) is generally similar to that used on locomotives E3001-23 except that semiconductor rectifiers are used instead of mercury arcs. The space and weight saved has permitted the introduction of rheostatic braking equipment.

The underframe and body are of all-welded construction. Mild steel plate is used for the lower body; aluminium panels riveted to light steel channels for the upper body. The bogies are similar to those fitted to the A E I (Rugby) locomotives, as are the motors and most of the circuits.

A slight change has been made in the rectifier circuit, from bi-phase to bridge. The main transformer has only two secondary windings for power, and the auto-transformer is simplified. The notching arrangement and the number of notches are unchanged.

The rectifier is built up with strings of eight germanium or seven silicon cells mounted on trays. The trays are mounted vertically in a frame and can be slid out for maintenance or complete removal. There are either 20 trays of germanium or 12 trays of silicon cells, each tray containing either 64 germanium or 28 silicon cells. There is no longer any need for the high-speed line breakers, and the circuit now includes two motor contactors per motor with separate overload protection for each motor.

Rheostatic braking is achieved by excitation of the traction motor fields from a separate step-down transformer whose primary is fed from the main transformer under the control of the main tap changer. The output of this transformer is fed through the normal power rectifiers. Thus the braking is controlled by the main control handle after movement of a selector switch to choose 'braking' instead of 'power'. During braking the four traction motor fields are connected in series with each other, and a fixed-value forced-ventilated braking resistor is connected across each armature. If rheostatic braking is not maintained once it has been selected, a partial air brake application is made automatically. The rheostatic brake gives a braking effort of 24 000 lb (10 900 kg) between 10 and 21 mile/h (16 and 34 km/h), falling to 8 000 lb (3 600 kg) at 70 mile/h (112 km/h). The power absorbed by the brake is approximately 1 000 kW.

The Railway Conference: Multiple Unit Trains

A fleet of about 400 multiple unit trains was required to meet the needs of suburban services in the electrification schemes. The suburban electrifications themselves differ considerably in character. A review of the problems and the trains produced was given in a paper (No 4) 'The Multiple Unit Trains' by H. Wilcock and C. J. Clemow, of the British Transport Commission.

The Chief Electrical Engineer's specification for the new equipment, while bearing in mind the different operating conditions throughout the country, set out a single set of parameters on which the offers received from the various manufacturers could be judged, and made provision for some adjustment to meet the special requirements of particular services.

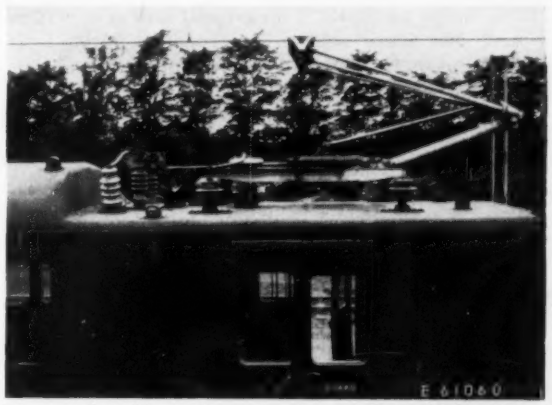
Performance requirements were stated as follows. The maximum service speed was to be 75 mile/h (120 km/h) with wheels worn to $36\frac{5}{8}$ in diameter (93 cm). The wheels were to be 40 inches in diameter when new (102 cm). Mean acceleration for a loaded four-coach unit was required to be 1·1 mile/hs (1·175 km/hs). Specification was also given of the performance in service that was expected of a fully seat-loaded passenger coach with half-worn wheels and 22·5/5·6 kV line voltage. The normal run from Liverpool Street to Southend (Victoria) was to be covered in 60 minutes, with six intermediate stops of 30 seconds each and with sufficient coasting to give 8 per cent make-up time. The stops are approximately 6 miles apart and the duty represents a schedule speed of 40 mile/h (64 km/h). After two normal trips such as this, the train should be capable of an emergency run from Shenfield to Southend and back without any coasting and with six intermediate stops of 20 seconds each on each trip. These stops are approximately 3 miles (4·8 km) apart. It was also essential that the loaded four-coach unit should be able to start on a gradient of 1 in 70 with two motors cut out. The rating was to be based on a four-coach unit tare weight of 153 tons (155·5 tonne).

The use of the specified motor coach in a three-coach unit formation gives an increased performance and ability to make more frequent stops without overloading. The acceleration is 1·35 mile/h/s (2·17 km/h/s).

Contracts placed cover equipments for 361 suburban multiple unit trains (1 301 vehicles) and equipments for conversion to a c working of 124 existing d c suburban multiple unit trains (404 vehicles). The greater part of the new rolling stock was built in British Railways workshops.

All units have a single forced-oil air-blast cooled main transformer with a primary winding made up of four equal sections and an electropneumatic changeover switch to enable these sections to be connected in series or parallel for operation at 25 or 6·25 kV. Tap changing is carried out on the secondary side by air-break contactors, either camshaft operated or in the form of electropneumatic unit switches, or combinations of both. Germanium and silicon rectifier units are now being introduced into service in quantity, but three contracts include mercury arc rectifiers. All motors are essentially normal d c machines, but with laminated commutating poles, and are axle hung with rubber nose suspensions.

The limitations of the British loading gauge, the standard floor height, and the necessity of providing adequate headroom in the guard's compartment under the lowered roof carrying the roof-mounted electrical equipment are factors which have resulted in the roof-mounted electrical equipment being contained in a space less than 26 inches (66 cm) deep. A Stone-Faively pantograph collects the supply for the train. The minimum of equipment is carried in the guard's van and comprises a low-tension cupboard, the internal operating gear of the circuit breaker, the transformer oil conservator, the auxiliary compressor, and certain other compressed air apparatus for pantograph and circuit breaker operation.



Pantograph and h t equipment on the roof of a multiple unit train

The control gear is designed in accordance with modern practice with features such as silver butt contacts for non-rupturing power contacts and for control contacts, maximum use of electropneumatic devices to reduce electrical control loads, and a considerable degree of miniaturisation. The control voltage is 110 V d c and train control is provided through 36 train lines and 36 point couplers. Power for auxiliaries originates from a 240 V winding on the main transformer. This is used for all heating, main compressor, battery charger, and auxiliary motors that are not required when the line voltage is absent. Fan motors and the oil pump motor are single-phase induction motors with capacitor starting and running.

Driver's controls are standardised. The master

controller is of the desk type to permit the driver to sit with his knees under it. The main handle incorporates a 'dead man' feature; the reverse handle is not removable. The former has the following positions: off, shunt, half-voltage, full-voltage, weak field. The brake controller for operation of the electropneumatic and Westinghouse automatic brakes has the following handle positions: running, continuous section for self lapping electropneumatic brake, full electropneumatic brake, Westinghouse brake lap, Westinghouse brake application, emergency application, and neutral.

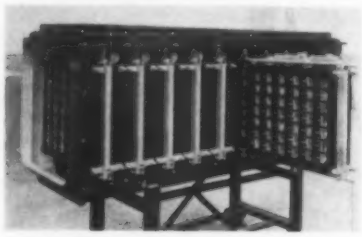
Manchester-Crewe Line (Paper No 24)

Equipment for 35 four-car units for Manchester-Crewe and 15 units for Liverpool-Crewe suburban services was produced by A E I (Rugby) Ltd. The equipment was described in a paper by M. W. T. Rees and R. Bugler, of Associated Electrical Industries Ltd. The design features peculiar to this stock are the fact that the electrical equipment under the motor coach has been mounted entirely in the side bays, keeping the centre section free for brake gear, pipework and cables, and that the main power and auxiliary rectifiers are made up of germanium diodes.

A bridge-connected rectifier scheme is used and the four traction motors are connected permanently in parallel. The total r m s d c current is about 700 A, and low voltage tap changing with air-break tap changing switches is used, controlled by a motor-driven camshaft. A tap changing reactor controls the inter-tap transformer circulating current by acting as a mid-point auto-transformer. To obtain a larger number of notches from a fairly simple camshaft, a buck-boost system of control is used. The motor voltage is stepped up during train acceleration in 17 steps from 5 transformer taps, using 10 camshaft operated contactors.

The camshaft is driven by a d c motor through a chain of reduction gears and Geneva mechanism. Accuracy of location is essential and is assured by a system of inter-notch interlocks that stop the shaft by dynamically braking the motor. A notching relay controls the automatic acceleration of the train.

The germanium rectifier consists of ten trays each having 48 cells. Each tray carries two fuses, each fuse feeding two parallel strings of cells. A hole storage capacitor is mounted on the underframe.



(Left) *A germanium rectifier assembly with one tray withdrawn and showing the 48 cells. Used on the Manchester and Liverpool M U stock equipped by A E I (Rugby).* (Right) *The A E I motor-driven camshaft tap changer incorporated in the Glasgow suburban trains*

No heating or excitation equipment is needed for the rectifiers, but adequate cooling is vital. The cells are mounted on aluminium fins and a fan blows approximately 3 500 cu ft/min (99 m^3/min) of air ducted from the outside of the coach. The air is not filtered but is drawn from the sides of the coach above the solebar level to avoid the very dirty air beneath the coach. It was considered highly preferable to accept unfiltered air rather than risk blocked filters and subsequent air starvation and cell failure.

The traction motors have the damping of the interpole magnetic circuit effectively reduced by the provision of shallow laminated ring segments clamped to the inside of the main yoke casting and bridging the poles; this improves the operation on rectified alternating current. Designated type MV 148, the motors are four-pole wave-wound types, insulated with Class B materials. On full field they are rated continuously at 975 V 165 A 190 s h p. On weak field and the same voltage the last two figures become 180 A and 210 s h p. Maximum speed is 2 820 rev/min.

Glasgow Suburban Lines (Paper No 27)

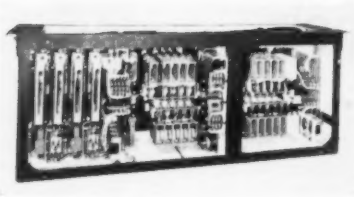
The first electrification project undertaken in the Scottish Region of British Railways gave rise to an order for 91 multiple unit trains from A E I (Manchester) Ltd. The composition of each unit is: driving trailer, motor coach, battery driving trailer. Their electrical equipment was described in a paper by G. R. Higgs and J. G. Sommerschield, of Associated Electrical Industries Ltd.

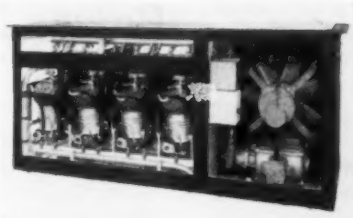
A low-tension tap changer working direct from a number of taps on the secondary winding of the transformer is used, together with four single-anode mercury arc rectifiers that are bridge-connected. The four traction motors are permanently connected in a series-parallel arrangement, the mid-point between each pair of series-connected motors being connected to a centre tapping on the main transformer secondary winding. Thus an effectively parallel combination of all motors is achieved.

The transformer secondary is provided with seven intermediate tappings of which one is mid-point; all are capable of carrying full load current. The switching sequence of the tap changer is such that consecutive notches are obtained by gradually increasing the voltage from one or other half of the transformer secondary winding, moving outwards from the mid-point. During transition from one tap to the next, an ohmic resistance is momentarily connected between taps. One or other of the two transition resistors is used to give intermediate voltages between taps.

The tap changer itself is a motor-driven camshaft; the 16 pairs of contact fingers have silver contact tips and are closed by springs and opened by cams. The contact breakers do not have to make or break currents; this is done by four electropneumatic air-break contactors.

Pumpless steel tank air-cooled mercury arc rectifiers are used. They are of the continuously excited type. Necessary preheating before the rectifiers are put on load in low ambient temperatures is achieved by connecting a resistor across the bridge output, which circulates 100 A when supplied at notch 1 voltage.





(Left) *The G E C electropneumatic cam-operated tapping switch.* (Centre) *Type C 7 'Compak' rectifier assembly for the Eastern Region M U trains.* (Right) *A side view of the train showing the under-car mounting of the rectifier*

London-Tilbury-Southend Line (Paper No 25)

In January 1957 the B T C ordered 112 sets of equipment from the English Electric Company Ltd for multiple unit stock, each unit consisting of four cars of which one is a motor coach with four motors. This electrical equipment was described in a paper by H. B. Calverley and E. Williams, of the English Electric Co Ltd.

Each phase of the bi-phase secondary winding of the main transformer consists of two portions—one with tappings and one without. The tapped portions are used twice during notching, first in series with reactors and then in series with the untapped portions. On-load tap changing is performed by contactors in conjunction with reactors, which are left in circuit on alternate notches to give pseudo mid-tappings. The decision to use contactors instead of a camshaft for tap changing was influenced by the fact that notching back was not required; electrical interlocking is therefore not difficult.

The tap changer feeds two pairs of air-cooled excitrons of the sealed tank type, each pair connected in bi-phase. Rectifier output voltage was considered to be too high for optimum motor design, so the traction motors are connected two in series. Weak field operation is obtained by tapping rather than by diverting the field to reduce the risk of flashover without resorting to inductive shunts. The two motor strings are connected through a common smoothing reactor to the centre point of the secondary winding. The centre points of the strings are connected by a low impedance equalising connection, whereby the behaviour of the motors under wheel-slip conditions approximates to that of parallel-connected motors. The equalising connection contains two wheel-slip relays with different settings, and is earthed through a low-impedance earth-fault relay and an earthing contactor.

The traction motors are self-ventilated four-pole series wound machines. They are continuously rated at 192 h p 620 V 250 A when in weak field and carrying undulating current. This rating corresponds to a line voltage of 22·5 kV. The permissible temperature rises of the armature and fields are 120 deg C and 130 deg C respectively. A weak field running notch is obtained by field tapping; no field diverts or laminated magnetic yoke are used.

Liverpool Street-Enfield-Bishop's Stortford Lines (Paper No 26)

Fifty-two three-coach units, each comprising a battery driving trailer, motor coach and driving trailer, and 19 four-coach units, similar to the three-coach units but with a trailer coach added, will operate these services. Both sets of units use electrical equipment produced by the G E C and described in a paper by R. Ledger and J. C. Turrall, of the General Electric Co Ltd.

The transformer secondary supplies two bridge mercury arc rectifier circuits, each feeding two traction motors in series. An equalising connection between the mid-points of each pair of motors reduces the rise in voltage on a motor which develops slip and thus assists recovery of adhesion. Motor voltage is controlled by tapping switches on the transformer secondary, using two contacts for each tap in conjunction with series resistances and a centre-tapped choke. By these means 20 steps are provided from nine taps, two of these being running steps with no series resistance in circuit. The earth connection in the motor circuit is at the mid-point of the transformer secondary.

The tapping switch is an electropneumatic camshaft-operated switch with cam-opened spring-closed contacts —a design that provides the necessary number of steps with the minimum of electrical interlocks. Adequate mechanical spacing between steps is obtained by using two camshafts, each with its own air engine.

Eight Compak single-anode rectifiers are fitted in each motor coach. They are a somewhat smaller version of the rectifiers used in this company's locomotives and have a simplified water cooling circuit.

The traction motors follow conventional d c practice except for the following features. They are about 5 per cent heavier than an equivalent d c motor, having been made 7 per cent larger in diameter and somewhat shorter in length to improve commutating conditions. A permanent field divert of 10 per cent is used to reduce flux pulsation to approximately 2 per cent. Eddy currents are reduced to a minimum by using thin pole stampings and by designing coil springs and washers to give the maximum resistance to circulating currents produced by the pulsating armature and interpole fields.

Make-up of a Typical Four-coach Multiple Unit Train

	Seating	Unladen weight	Laden weight	Length
Battery driving trailer, open second class vehicle	80	35·8 tons 36 370 kg	40·8 tons 41 450 kg	63 ft 11½ in 19·5 m
Motor luggage compartment, second class vehicle	96	54·4 tons 55 272 kg	60·4 tons 61 370 kg	63 ft 6 in 19·4 m
Trailer composite, first and second class vehicle	19 + 60	30·5 tons 30 989 kg	35·5 tons 36 069 kg	63 ft 6 in 19·4 m
Driving trailer compartment, second class vehicle	108	32·1 tons 32 615 kg	38·9 tons 39 423 kg	63 ft 11½ in 19·5 m

The Railway Conference: Power Supply

A DESCRIPTION of the considerations governing the design of the railway power supply system was given in a paper (No 5): 'The Power Supply', by W. J. Webb, of the British Transport Commission. Primarily, the distance between points of supply to the overhead contact system is determined from consideration of the traffic to be handled, the performance required of the electric tractors, and the electrical characteristics of the overhead and supply systems.

These and other considerations have led to a feeder-station spacing of about 25 miles (40 km) in Britain. The impedances of the overhead line used in the calculations for this figure were 0·47 Ω/mile (0·77 Ω/km) of two-track length where no booster transformers and return conductors are installed, and 0·7 Ω/mile (1·12 Ω/km) of two-track length with booster transformers and return conductors. With these impedances, the 25 mile spacing is suitable for working a service of 10 trains an hour at an average speed of 60 mile/h (97 km/h) when hauled by electric locomotives each taking the maximum accelerating current of 270 A. This is on the basis of 16·5 kV minimum voltage at the locomotives for a nominal line pressure of 25 kV. Calculations for the 6·25 kV system show that for the conditions where booster transformers and return conductors are installed, the ideal spacing for this lower voltage system is about 5½ miles (8·8 km), on the basis of a maximum value of the peak accelerating current of 1 050 A per train and with both ends of the overhead line fed in parallel.

Supplies to the feeder stations are taken from the main step-down transformers through concentric 25 kV cables, except where circumstances permit overhead lines. At the feeder station the inner conductor of the concentric cable is taken through a single-pole circuit breaker to a busbar from which the supply is distributed through single-pole circuit breaker equipments to the overhead conductor lines. The outer conductor of the concentric cable is taken to a busbar designated the 'earthy' busbar, which is connected by insulated cables to the running rails. To cater for the railway load, a range of sizes of 132/25 kV transformers is used: 15, 10, 7·5 and 5 MVA. The short-circuit duty of the 132 kV circuit at the point of supply ranges from 1 500 MVA to 3 000 MVA at large capacity stations. For the 25 kV switchgear, two short-circuit ratings have been adopted: 300 and 150 MVA. An impulse-withstand test of 200 kV has been adopted for all 25 kV switchgear.

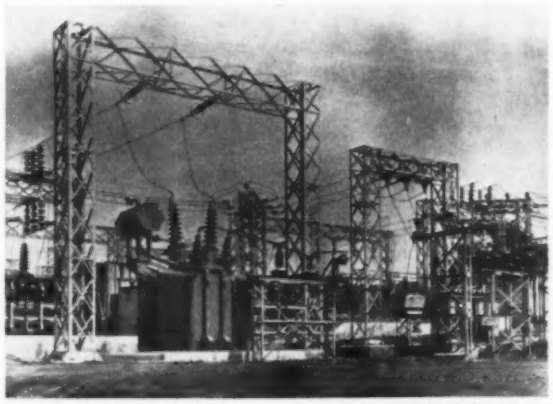
The two main factors to be considered in providing single-phase track supplies to the railways from the public supply system are unbalanced loads and harmonics. These were discussed in a paper (No 28): 'Power Supply: The Railway Load', by W. Casson, of the Central Electricity Generating Board, and W. L. Kidd, of the South of Scotland Electricity Board. Unbalanced loads can cause unbalanced voltages that in turn produce unbalanced currents from balanced loads fed from the same source; they restrict the capacity of the network to supply 3-phase loads for distribution, and they cause unbalanced current to flow in the generators, producing overheating of the rotors. Harmonics may cause overloading of capacitors and other plant. However, experience on the Lancaster-Morecambe-Heysham line using single-phase 6·6 kV supplies from the North-Western Electricity Board's 6·6 kV system based at Lancaster has not produced any unbalanced load or harmonic problems, and difficulties are not expected from the 25 kV systems, provided the larger loads are taken direct from the 132 kV system.

Feeder Station Equipment

When the electrification project was started there existed in the U K no proved design of 25 kV single-phase circuit-breaker equipment of the required capacity and duty suitable for railway service. Two designs were selected from the types offered by manufacturers. Both designs are of the cubicle type but one is air-insulated and the other oil-insulated.

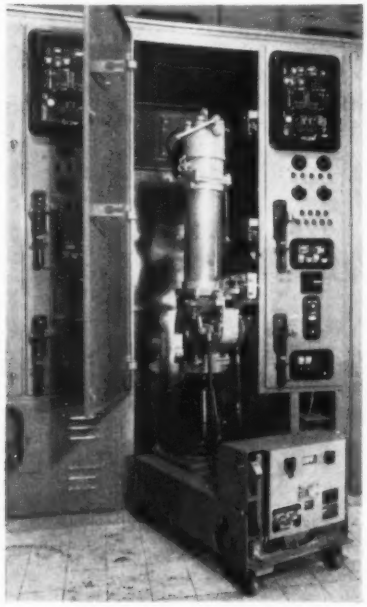
The latter was described in a paper (No 29): 'Power Supply: Oil-insulated Switchgear', by F. G. Rowland, of Switchgear and Cowans Ltd. The design is based on established 3-phase switchgear that has been in production for seven years. The circuit breakers are of the single-pole indoor fixed dead tank type and two groups have been developed: one for 25 kV 330 MVA and one for 6·25 kV 165 MVA. They are fitted with a patented single-break compensated pressure arc interrupter and trip-free solenoid closing mechanism. Each circuit breaker is provided with hand-operated isolators to provide for complete isolation; the isolators are interlocked with the circuit breaker.

The air-insulated type was described in a paper (No 30): 'Power Supply: Air-insulated Switchgear', by A. J. Haselfoot and G. T. D. Ingle, of Fuller Electric Ltd. These 25 kV circuit breakers are single-pole indoor oil minimum extraction type of similar design to a smaller version that has proved very satisfactory in service with the Swedish State Railways 16⅔ c/s 16 kV single-phase electrification system.



5 MVA 132/25 kV single phase transformers built by Bruce Peebles & Co Ltd for the North of Scotland Hydro-Electric Board and used for supplying power to the Glasgow suburban electrification system

They have been re-designed so that access to the circuit-breaker compartment is obtained through a door in the front of the switchboard, and since the circuit breaker itself is mounted on wheels and has a flexible plug-in connection for small wiring, it may be wheeled out into the aisle for inspection and maintenance. The use of inflammable material has been reduced to a minimum. On an 11-panel switchboard including nine circuit breakers and four voltage transformers the total quantity of oil is only 55 gal (250 litres).



A track feeder cubicle by Fuller Electric Ltd with the door open and the circuit breaker withdrawn. It is rated at 25 kV 800 A with a breaking capacity of 300 MVA

Feeder Protection

Following normal practice, the supply transformers are provided with balanced earth fault protection on both the high and low voltage sides, together with Buchholz winding temperature and high-voltage overcurrent protection. The supply feeders are protected by a Merz-Price balanced voltage system of protection with provision for intertripping; the system is usually of the Solkor pattern.

The protection of the overhead contact system is of the definite distance impedance type. This has the advantage over an overcurrent system in that variation in tripping time is determined by variation in impedance instead of current magnitude. Two types of equipment are used, and these were described in a paper (No 31): 'Power Supply: Protection Systems', by F. M. Pearce, of A E I Ltd, and G. T. D. Ingle, of Fuller Electric Ltd.

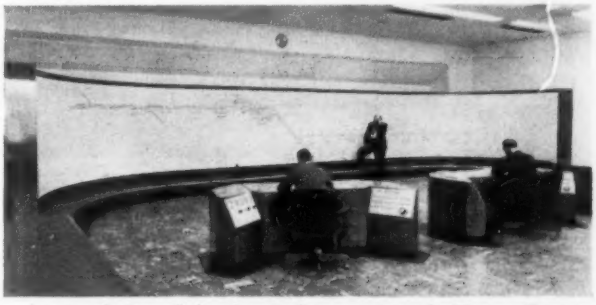
In the 400 A E I equipments supplied to British Railways the fault is detected by a 'rough' impedance measuring element with a mho-type characteristic whose function is starting and assessment of fault direction. An accurate measurement of the fault position is made by a second element controlled from the first, having an impedance-type characteristic and measuring in three zones. To extend the ability of the distance protection to provide high-speed fault clearance, particularly on short track sections, an optional pilot acceleration feature is provided, which enables tripping of the distance protection at one end of a track circuit to send a d c signal over a pair of signalling pilots to cause instantaneous operation of the protection at the opposite end, that is, overriding any zone time delay.

In the 180 equipments supplied by Fuller Electric Ltd for service on the Eastern Region, faults are detected by a relay sensitive to sudden current increases. This initiates tripping of the circuit breaker if the location of the fault, as determined by an accurate induction cup impedance measuring relay, lies in the protected zones.

The variation of tripping time in accordance with variation of impedance, as produced by both these equipments, is particularly advantageous in the case of faults on the overhead system, where prolongation of the fault current necessary to give an overcurrent system time to act might severely damage the conductors. The system is backed up by a long-time thermal relay to provide for tripping on the occurrence of a long sustained overload.

Supervisory Remote Control

To ensure continuity of power supply to the tracks it is necessary to have a comprehensive picture of supply conditions and the means to operate switchgear with the minimum of delay at all the feeder stations and track sectioning cabins. The electrified lines are therefore divided into 'electrical control areas', each with its electric control station. An area may comprise 40 or 50 controlled stations; the most distant station may be 60 or 70 miles (96 or 113 km) from the control station, which may exercise control of 700 items concerned with the power supply to some 600 track miles (966 km). This network was described in a paper (No 32): 'Power Supply: Remote Control of Power Distribution', by A. H. Cole, of the British Transport Commission, G. A. Burns, of the Automatic Telephone & Electric Co Ltd, and G. Gordon, of Standard Telephones & Cables Ltd.



A general view of the electrical power control office at Crewe showing the mimic switchboard referred to in this column

A voice-frequency system of signalling is used, to avoid magnetically-induced disturbances from the traction currents. All switch operations are effected from a vertical mimic switchboard at the control station. Signal transmission is by pilot wires, one pair for outgoing operating signals and one pair for incoming indicating signals. Up to 12 stations can be served by one set of four pilot wires, such a group being termed a 'system'. The pilot lines are duplicated and line changeover equipment is provided. Additional pairs are provided for telephone speech circuits.

The A T E Co Ltd have adopted the use of two frequencies. One frequency common to all stations is used, together with a second frequency that is particular to the station concerned. When station and common frequency are applied to the outgoing pair of the line, their reception by the correct station is indicated by that station's frequency returning on the incoming pair to the control station. Common frequency is then removed from the outgoing pair and an impulse code is sent out to select the group which includes the device that it is desired to operate. This code consists first, of from one to three pulses at station frequency, followed by the necessary number of pulses at common frequency to make up a total of four pulses. Without any break in the impulse train, the requisite number of station frequency pulses to select the desired device in the group is sent out, followed by sufficient common frequency pulses to make a total of 25 pulses.

As the device operates, its auxiliary contacts change over and cause either common or station frequency to be sent out to the control station, depending on whether the device has moved to the open or closed position; this cancels the selection and restores the equipment to its normal state, ready for the next operation.

S T C Ltd use a frequency-modulated system wherein the pulses are transmitted by modulating a single basic frequency. The two line conditions provided by this method of signalling are derived by shifting the fundamental frequency to either 30 c/s above or 30 c/s below its normal value. Basically, it is these 'opposite direction' changes that enable the pulses to be distinguished from each other and to be counted. The station, group, and device within the group are selected by trains of pulses, and following a check-back signal from the station selected, the control station apparatus checks that the station has received the correct code. A train of pulses then effects the operation desired.

When a device at a station operates automatically or is operated locally, the station apparatus transmits a train of pulses which indicates both the group in which the change has taken place and also complete information concerning all the switchgear items in that group.

Booster Transformers

The decision to install booster transformers either with or without return conductors as a means of limiting induced interference voltages brings with it certain problems to the power supply. The transformers are in effect power current transformers with unity ratio and are used with their primary windings connected in series with the overhead line and with their secondaries connected either directly to the running rails or to a special return conductor. Their most important effect from the power supply point of view is to increase the impedance of the circuit, which means that its influence on voltage drop must be carefully taken into account if the performance of the traction equipment is not to be adversely affected. The transformers also affect the definite distance impedance protective system and alter the potential of the rail to earth.

For the peak accelerating currents for the electric locomotives and multiple unit trains, consideration of the induction compensating requirements results in a spacing of about one mile (1·6 km) for booster transformers with direct rail connection and about two miles (3·2 km) for transformers with return conductors. In the latter case the secondary voltage of the transformer varies with the impedance of the return conductor and so the capacity of the transformer varies in an inverse manner with the size of the conductor. Consequently, the most economical arrangement results from comparison of the costs, including losses, of different sized return conductors and their matching booster transformers. From these considerations a range of transformers with mean current capacities of between 100 and 400 A has been adopted and contracts for them have been placed with Fuller Electric Ltd and Foster Transformers Ltd.

A feeder station under construction at Colchester on the Eastern Region, with equipment by Foster Transformers Ltd

Cables

The incoming 25 kV supplies from the grid are through two-core concentric pressure cables at 25 kV to earth. The same type is used for connections between railway feeder stations. Generally the cables are of the oil-filled type but some are gas-filled. Cables having copper conductors and lead alloy sheaths and cables having aluminium conductors and corrugated aluminium sheaths have been installed. At Crewe, the incoming 25 kV supply cables have copper conductors of 0·85 sq in (548 mm^2) cross-sectional area, but usually 0·50 sq in (323 mm^2) conductors are sufficient where the supply transformers are rated at 15 MVA, as at Crewe.

Pilot cables for the main feeder supply protection are of the 110 V mass-impregnated type and have either four or seven conductors each of 7/0·036 sq in (23 mm^2). The connections from the switchgear to the 25 kV overhead contact system are formed of 25 kV single-core solid type cables. To date either 0·15 sq in (97 mm^2) or 0·2 sq in (129 mm^2) copper conductor lead alloy 'B' sheathed mass-impregnated paper insulated cables have been installed, but on later installations trials are to be made on 25 kV mass-impregnated non-draining type cables.

Contracts for the supply of cables to standard specifications have been awarded to Aberdare Cables Ltd, Associated Electrical Industries Ltd, British Insulated Callender's Cables Ltd, Enfield-Standard Power Cables Ltd, Johnson & Phillips Ltd, Pirelli-General Cable Works Ltd, Scottish Cables Ltd, and W. T. Glover & Co Ltd.

The Railway Conference: Overhead Line Equipment

CONSIDERATIONS of overriding importance which do not exist elsewhere and which control the design of overhead equipment in Britain were outlined in a paper (No 6): 'The Overhead Line Equipment', by E. Claxton, of the British Transport Commission.

While the traffic density on the principal lines in Britain is heavy in terms of ton-miles per single track running mile per annum, being sometimes as high as eight million, the average train is not heavy. Thus the number of trains each day is very large, ranging from 50 to 150 or more in each direction during the 24 hours. Consequently, the maintenance of supply to the overhead line is of first importance.

Space available for trackside equipment is generally much more restricted in Britain than in other countries. There are generally many overbridges—an average of 1½ to 2 per route mile (1·6 km). Further, the small rolling stock loading gauge is very little less than the structural gauge. Tunnels, too, are frequent and of restricted clearance. Finally, the degree of atmospheric pollution, especially in the neighbourhood of railway lines, is frequently heavy, while a moist climate and the continuing presence of steam locomotives add to this problem.

In a paper (No 7): 'The Erection of the Overhead Line Equipment', by J. W. Grieve and A. H. Emerson, of British Railways, the authors point out the large amount of civil engineering work that has to be done before the overhead equipment can be installed.

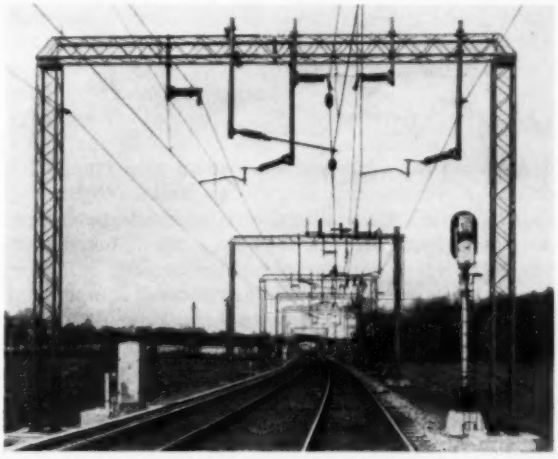
Electrification calls for many vehicles for work trains, as well as personnel. The installation of 200 single track miles (322 km) of overhead equipment in the very complicated network of lines including the junction and sidings at Crewe occupied 26 500 works train-hours and 75 000 lookout man-hours. An example of the speed at which bridge operations were carried out by blasting was given in a paper (No. 8): 'Civil Engineering Aspects', by A. K. Terris, of British Railways. Only 100 minutes have been needed after blowing up to clear one line for traffic.

In the same paper the effect of irregularities in the track on current collection are stressed. Up to the present it has been agreed that, in the ordinary course of maintenance, deviations of 1 inch (2·54 cm) in alignment and 0·75 inch (1·9 cm) in cross-level are to be regarded as the maximum permissible amounts.

Fittings have been developed to meet the special conditions under low bridges and in tunnels to maintain a high standard of performance. The success achieved can be appreciated from the fact that substantially sparkless collection is obtained with an equipment depth of less than 1 inch (2·54 cm) at minimum wire height at speeds up to 100 mile/h (160 km/h).

The pollution situation outlined above makes conditions in Britain very bad for insulators and the problem of designing suitable insulators for the electrification scheme was referred to The BEAMA, who formed a small committee of manufacturers with wide experience of the operation of insulators in such conditions. The firms represented were Bullers Ltd, Doulton's Industrial Porcelains Ltd, Steatite & Porcelain Products Ltd, and Taylor, Tunnicliff & Co Ltd.

A description of the insulators evolved was given in a paper (No 34): 'Overhead Equipment: Insulators', by C. H. W. Clark, of Steatite & Porcelain Products Ltd. The insulators now in use at 25 kV include some with a creepage distance of 51 inches (130 cm), obtained by the use of eight deeply ribbed sheds. Others have eight sheds giving creepage distances of 42 or 49 inches (107 or 122 cm). The diameter of the sheds varies from 6·375 to 9·5 inches (16·2 to 24·1 cm). On track isolators, post insulators with 12 plain sheds have been used, giving a creepage distance of 45 inches (115 cm). For 6·25 kV sections, solid core insulators with 2, 3, or 4 sheds, giving a creepage distance of 16 inches (40·6 cm), have been used for line supports and isolators.



A carrier wire neutral section as described on the next page. These are introduced at points where the overhead lines are connected to different phases of the supply network or where the system voltage is reduced to 6.25 kV

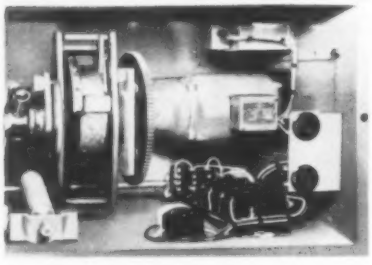
There has been an unusually extensive use of insulators in situations where they are subjected to bending stresses, for supporting the catenary itself. A mechanical factor of safety of 3·5 inches (89 mm) bending has been generally employed and reliability to date has been good.

Recent developments in insulator construction were described in a paper (No 33A): 'Developments in Overhead Equipment', by S. H. R. Proud and J. R. Pugh, of British Insulated Callender's Cables Ltd. Limited field trials of P T F E-protected glass fibre insulators at 25 kV were put in hand in March 1959 on the line between Crewe and Manchester. At the present time there are representative insulators in service at conductor terminations, section insulators, and in cantilever assemblies. These have not been cleaned and are in excellent con-

dition. For other applications, consideration is being given to the use of the high-strength alumina ceramics and devitrified glass.

The Catenary System

A description of the catenary system was given in a paper (No 33): 'Overhead Equipment: The Catenary System', by C. E. Allen, of British Insulated Callender's Construction Co Ltd, and A. G. Goldring, of the British Transport Commission. In general, and certainly where speeds are high, conductors are automatically tensioned by means of weights. On single or double tracks the overhead equipment for each track is separately supported on cantilevers which are free to swing along-track to allow for movement of the conductors as they expand or contract. On three or more tracks, where portal structures are used, the main catenary wires are carried on pulleys attached to insulators mounted either vertically above or horizontally beneath the structure boom.



Interior view of the motor-wound spring mechanism supplied by Switchgear & Equipment Ltd for operating track section isolators

Allowing for wind and ice loading and a maximum off-set of the contact wire of 19 inches (48·3 cm), a span length of 240 feet (73 m) was decided on, based upon normal staggers of 9 inches (22·9 cm) on tangent and 15 inches (38·1 cm) on curved track. The maximum length of a section of weight-tensioned equipment is about 1·25 miles (2 km), or roughly 28 spans between anchor points. The main catenary is anchored on a structure at or near the centre of each length of weight-tensioned equipment; but on gradients of 1/100 or steeper, the length of each section of equipment is reduced to half that normally allowed and attachment is made to a fixed anchorage at the uphill end.

Both compound- and simple-stitched catenaries have been used, but comparison in service clearly indicated that the former was preferable and use of the latter has been discontinued. Simple fixed-termination equipment has been used for certain complicated layouts.

Beneath overbridges and in tunnels, special forms of construction have been adopted. Where clearances permit, the contact wire is suspended below the main catenary in the normal way, the minimum dimension between the contact and the catenary wire at the supports being 6·25 inches (15·9 cm). Where necessary, the required clearance is reduced by using twin contact-wire construction, wherein a length of contact wire is inserted into the catenary and is then run alongside the through contact wire. More frequent supports are required for this form of construction, but the depth of equipment between supports is reduced to less than 1 inch (2·54 cm).

When the steelwork and registration fittings have been erected as far as possible, the catenary is run out from the pre-assembled balance weight anchor locations at one end of the tension length through rollers at each supporting structure, is tensioned correctly and is then finally made off at the balance weight anchor at the other end. The process was described in a paper (No 36): 'Overhead Equipment: Erection', by T. H. Rosbotham, of British Insulated Callender's Construction Co Ltd, and I. J. Hall, of Pirelli-General Cable Works Ltd. The contact wire is run out next, on droppers from the main catenary, and is tensioned so that it just begins to take the load of the balance weights. The catenary can be cut at the mid-point anchor, check-tensioned, and finally made off through appropriate insulators. Generally, the conductors are run out from a wiring train of six or seven flat-topped coaches and drum wagons.

Neutral Sections

Design considerations for neutral sections on British Railways were severe. Because of the frequent location of feeder stations at junctions in congested areas, the length of neutral sections had to be kept to the minimum to avoid inconvenience to traffic; the operation of multiple unit trains of various formations postulated a multi-gap design to avoid bridging the two live sections; it was thought prudent to allow initially for locomotives operating with two pantographs raised, and up to two together; it was considered necessary to make the passage through the neutral sections completely automatic to reduce loss of power to a minimum.

As a consequence, neutral sections were designed with four gaps and magnetic inductors were located outside the running rails before and after each section. A receiver on the locomotive or motor coach is operated as it passes over the first inductor and cuts off and locks out the power circuits. The second inductor initiates the reverse operation.

Two types of neutral section have been used. Carrier wire neutral sections are used where speeds exceed 60 mile/h (96·5 km/h) and consist of four overlap spans in series, an additional set of overhead equipment being introduced alongside the through equipment so that they may each be lifted out-of-running in turn to form the overlap spans. The distance over which current cannot be collected is about 270 feet (82 m), and this presents some difficulty with respect to signals.

Section insulator neutral sections are used at present only where speeds are 60 mile/h (96·5 km/h) or less and consist of four section insulators in series at 40 feet (12 m) intervals, the equipment being supported 6 feet (1·83 m) in advance of each section insulator. This type of neutral section is cheap and simple to install and the length of dead section is only 120 feet (36·5 m). A light high-speed section insulator that has been developed, incorporating two P T F E-covered glass fibre insulating tension members, will permit the use of this type of neutral section for all speeds. It is expected that still further simplification and weight reduction will be achieved by using only short lengths of glass insulation in running. These developments will also permit the more extensive use of dead sections under low bridges.

Isolating Switches

The traffic conditions require a high degree of sectionalising of the overhead equipment so that sections isolated

for defect or repair may be small. To reduce risks and time in applying maintenance earths and to ensure a secure earth should an electric train violate an isolated section, close/open/earth switches are provided at each end of each section. Alternative feed close/open/close switches and two-position close/open switches are also required. The majority are hand operated but in some cases remote or supervisory operation is needed.

Several designs of horizontal, rotating pedestal switches were developed by Electric Transmission Ltd, Hackbridge & Hewittic Electric Co Ltd, Switchgear & Equipment Ltd, and Bertram Thomas Ltd to a common specification that ensured that all would have the same performance and the same principal dimensions. For 25 kV operation, the fault level is specified at 300 MVA with a fault duration of 12 kA for 3 secs.

A single design of motor-operating mechanism has been developed to work with all types of switches. It operates on 240 V a c and is of the motor-wound spring-operated type to ensure that operation, once initiated, will proceed to completion.

Design of the overhead line and its supports has been done for the British Transport Commission under contract, principally by British Insulated Callender's Cables Ltd in association with and under the direction of the Chief Electrical Engineer. Pirelli-General Cable Works Ltd have been directly concerned with special and alternative equipment designs for Scotland.

Pantographs

A standard form of pantograph is used for all 25/6·25 kV locomotives and multiple unit trains. They are known as type AM-BR and derive from the pantograph type AM developed by Etablissements L. Faiveley, Paris, in association with the S N C F. They have been produced under licence by J. Stone & Co (Deptford) Ltd to the specification and under the guidance of the British Transport Commission.

Conditions of operation are severe compared with those normally encountered. The restricted loading gauge, coupled with the large wheels, reduces the room available for the pantograph, and so does the weight restriction that limits the length of the locomotive. At the same time, the total range over which sparkless current collection is required is from 13 feet 5 inches to 20 feet 6 inches (4·1 to 6·25 m), and on many sections of the electrified line the contact wire frequently varies from one extreme to the other from its normal height of 16 feet (4·87 m) above track on account of over-bridges or level crossings, frequently close to one another. Because of the traffic pattern on British Railways, it is essential that contact wear is reduced to a minimum to avoid maintenance. This demanded the use of graphite collector strips—a major difference between the AM-BR pantograph and its French prototype. The frequency of junctions and crossovers and the high cost of obtaining the necessary air clearance for insulation account for other differences, such as the use of a curved pan capable of collecting current over its whole width of 5 feet 3 inches (1·6 m), and arrangements to avoid tilting the pan transverse to the track.

Two other special factors remain to be mentioned. First, that current collection is required at full power both at 25 and 6·25 kV up to speeds of 100 mile/h (160 km/h). Second, the pantograph must not only be able to collect satisfactorily from the light overhead equipment of the high voltage a c electrification scheme but also from the much heavier equipment installed for the Liverpool Street–Shenfield 1949 electrification and retained in commission after the conversion to 6·25 kV.

To meet the foregoing requirements a pantograph of elegant design and manufactured with great precision is called for. A description of the standard pattern adopted was given in a paper (No 20): 'Pantographs for Locomotives and Multiple Unit Trains', by E. E. Chapman, of J. Stone and Co (Deptford) Ltd.

The collector head assembly, which is as light as possible, is connected to the main articulated system by separate resilient mountings to ensure the maximum response to small changes in the height of the contact wire. The arrangement is such that the virtual fore-and-aft centre of rotation of the collector head is at or above the point of contact with the overhead line. The resilient mounting provides for a fore-and-aft variation from the horizontal position, under normal service conditions, of up to $\pm 5°$. All pantographs so far supplied have been fitted with metallised carbon made by the Morgan Crucible Co Ltd, which has the advantage of being stronger and having a higher current-carrying capacity than plain carbon and still providing a lubricating medium.

The main articulated system is of robust construction, while having low inertia and high lateral stability. Its main supporting member is an exceptionally strong tubular T-piece which, since it forms the lower part of the articulated system, has only a small effect on the inertia of the pantograph as a whole. The lateral stability of the complete articulated system is such that a side force of 110 lb (50 kg) applied at the head does not produce a displacement exceeding 1·25 inches (3·17 cm) at this point.

Contact pressure, the resultant of the static upward force developed by the working springs and the aero-dynamic forces, has been limited to 25 lb (11·3 kg), arranged such that 20 lb (9·1 kg) are produced by the static force. At any loaded equilibrium position a difference in vertical force at the head of not more than $\pm 2\frac{1}{2}$ oz (71 g) will cause upward or downward movement.

The Railway Conference: Signalling and Interference

Signalling

The general overall speed increases on electrified lines, coupled with the expected increase in traffic density, necessitated a new signal system to give adequate braking distances together with the headways of from two to five minutes required by the new services. Experience with early a c traction systems indicated that the extent of electrical interference that could be expected with signalling and communication circuits would be severe. The steps taken to overcome these problems were outlined in a paper (No 10): 'Signalling and Telecommunications', by A. W. Woodbridge, of the British Transport Commission.

Track circuits are used as a means of detecting the presence of a vehicle within defined points on the track. But whereas the traction engineer requires the rails to act as a single solid conductor, the signal engineer makes use of the fact that the sleepers provide sufficient insulation for the rails to be used as a flow and return circuit, with the axles of the vehicle providing the crossover path.

With the advent of 50 c/s a c traction, the established 50 c/s signalling system had to be abandoned. Direct current track circuits provide the simplest solution and are used where only one rail is required for traction return and no d c traction interference is expected. In addition, steps had to be taken to immunise relays against interference from a c.

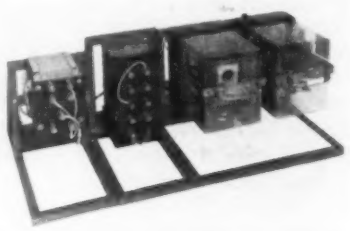
The A E I-G R S type B1 relay developed for this purpose was described in a paper (No 38): 'Signalling Equipment (A E I-G R S)', by G. I. Foster, of Associated Electrical Industries Ltd. In this type, protection against a c operation is obtained by fitting copper slugs on the cores between the coils and the armature air gap. Magnetic shunt strips are fitted, linking the cores between the coils and the copper slugs. Such a relay is guaranteed against pick-up on a c at any voltage below 1 kV a c. In practice it has been found that the relay will not pick up at any value below that at which flash-over at the coils would take place.

To give further protection, high impedance chokes having a d c resistance of 14 Ω and an a c impedance of 785 Ω at 50 c/s were inserted in series with the relay.

The direct current for the track circuit was obtained by rectifying an a c supply, and it was apparent that reverse operation was possible in so far as the a c potential across the rails would give rise to a half-wave rectified current that was effectively d c and possibly capable of adversely affecting the track circuit operation. In a paper (No 40): 'Signalling Equipment (Westinghouse Brake and Signal Co Ltd)', by D. G. Shipp, of the Westinghouse Brake and Signal Co Ltd, a circuit devised for overcoming this risk was described. Protection is afforded by a normally energised relay that compares the output of the feed rectifier against a fixed reference voltage, and which becomes released to disconnect the feed set from the rails if the rectifier output exceeds a value that could impair the safety of track circuit operation. Normally, this tripping point corresponds to an abnormal interference of 400 V, but full protection is still afforded, although at a lower interference voltage, if defects of any kind occur in the filter elements.

The d c track circuits of the single rail type are limited to lengths of 500 yards (457 m), and consideration was given to ways of increasing this length. The use of a c in conjunction with impedance bonds in the track, which by balancing the traction return current would considerably increase the permissible length, was investigated. The generation and distribution of a c at a different frequency would be a costly and cumbersome solution and the most attractive proposal was that of a track circuit using its own individual frequency generator (tied to the basic 50 c/s) at the feed end, with an accurate fail-safe frequency discriminator in the circuit at the relay end.

Four-aspect colour light signal with direction route indicator by Westinghouse Brake & Signal Co Ltd



Westinghouse 83⅓ c/s single track circuit equipment

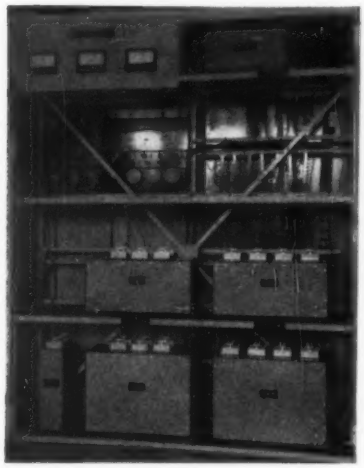
The system produced a 75 c/s output when fed at 50 c/s and at the relay end the output from the discriminator was rectified and fed to an orthodox d c relay. This equipment has proved fully effective in operation but suffers from the disability that its phase relationship with other similar equipment is arbitrary, and this makes it inadvisable to use the same equipment on adjacent sections.

A further factor that has influenced the preference for single rail d c circuits is that, on the average, track circuits in Britain tend to be shorter than those found overseas. If the average track length is less than about 1 200 yards (1 100 m) the economics favour the use of the d c equipment.

Special considerations applied to the sections of line originally electrified at 1 500 V d c and which had to

be converted to the new system. They comprised some 180 single track miles (290 km) of continuous track-circuiting with over 1 000 individual sections. Clearly, d c track circuits were out of the question as this would mean the overnight changeover of all the equipment.

The majority of the track relays installed were of modern design, either plug-in or detachable top, and a great deal of work could be saved in re-wiring if the same basic units could be employed. Thus, it was decided to convert these track circuits to operate on a 83⅓ c/s supply, protection against false operation by the 50 c/s traction current being obtained first, by frequency selection in the track winding circuit of the relay and second, by feeding the local winding from a second phase entirely independent from the one feeding the rails and protected against induced 50 c/s currents.



'Westronic' remote control equipment in its self-contained cubicle installed in the Sandbach signal box on the London Midland Region

The circuits use to the full the inherent advantage offered by the double-element vane type relay in that there must be a proper relationship in frequency and phase of the currents fed to the two elements before operation can occur. As was pointed out in a paper (No 39): 'Signalling Equipment (Siemens and General Electric Railway Signal Co Ltd)', by H. J. N. Riddle, of the Siemens and General Electric Railway Signal Co Ltd, such a relay gives equal protection against alternating currents of non-signalling frequency as it gives against d c traction currents. Provided any interfering frequency in the control element differs by some 5 to 10 c/s from the frequency of the current in the local element, no progressive movement of the vane results, and at the most some vibratory movement occurs. The supply to the local coil of the relay is carried in screened cables and monitored at the distribution point to give an alarm if more than a very low level of potential at traction frequency appears in this supply.

Interference

The problems of interference by the electrification system with light current circuits such as those used for signalling and telecommunications were discussed in a paper (No 9): 'The Interference Problem', by H. R. J. Klewe, of the British Transport Commission. In the new system, using the running rails for the return of traction current, the unbalance is intrinsically high, being 100 per cent for the electric field and about 50 per cent for the magnetic field. The interference is higher and more pronounced with 50 c/s currents than with lower frequencies or d c, where only transient conditions cause interference.

Fundamentally, the interference problem overseas is the same as in Britain. It is, however, different in degree, and the remedial measures adopted in Britain may not be needed elsewhere. It is evident that the nature of the existing telephone network has a pronounced bearing on the solutions adopted to counter interference.

The relevant features of the British telephone network were well brought out in a paper (No 37): 'Effect on Post Office Circuits', by D. W. R. Cobbe and B. R. Horsfield, of the Post Office Engineering Department. Over 7½ million telephones connected to some 6 000 exchanges serve the British system, and the density in terms of telephones per square mile is the second highest in the world: 78 compared with Switzerland's 87. The exchanges are interconnected by an extensive network of circuits, largely in unarmoured lead-sheathed cable, of which the shorter distance circuits (called junction circuits) in general use d c signalling. The electrification of the British Railways system at such a late date in the development of the telephone network could give rise to extremely serious interference problems. A detailed study of the effect of a 40 mile (64 km) section of electrification between Manchester and Crewe showed on a theoretical basis that without suppression at source some 1 600 circuits, of which 1 400 were junction circuits, would be adversely affected. Individual subscribers' lines, telegraph, and television circuits would also be affected.

The 'up' and 'down' fast train describer, control panel and indicator board installed by Standard Telephones & Cables Ltd in the St. Pancras, London, signal box

D C signalling equipment employs the earth-connected exchange battery for line signalling and is susceptible to the effects of induced voltages. Induced voltages between 5 and 20 V could give rise to excessive dial pulse distortion, false switching, false supervision, and false signals. On subscribers' lines, induced voltages could give rise to false bell ringing, false release, failure to operate metering, and false engaged test.

Tests were made to see whether longitudinal chokes could be used to improve the immunity of the d c signalling system, but inductances of less than 10 H have

not been found to have any significant effect and inductances having higher values introduce other pulsing difficulties. Consideration was also given to the use of signalling terminations embodying transformers and signal repeating relays, but this solution would involve extensive modifications to existing plant, and additional pulse distortion would be produced by the measures necessary to overcome noise interference. Longitudinal chokes are useful in reducing noise interference at harmonic frequencies, but their effectiveness is limited unless they are accompanied by shunt paths to earth, in which case unacceptable pulse distortion is introduced, together with transmission impairment.

In general, radical compensation at source has had to be adopted, with the use of booster transformers at two-mile (3·2 km) spacing with or without return conductors. They provide a very, but not fully, effective protection against magnetic induction. Actual methods used in the various electrification schemes are shown in the table below.

Radio Noise

Studies made of the radio noise generated by the electrification scheme were reported in a paper (No 37a): 'Television Interference', by G. A. C. R. Britton, of the Post Office Engineering Department. Unless grid-controlled rectifiers, which can give rise to steep-fronted current pulses, are used to obtain the traction d c supply, there is little likelihood of excessive radio noise being produced by the traction equipment itself. Noise from control and operating circuits can be dealt with by well-known techniques.

Sparking, as distinct from arcing, can occur at the current collector of an alternating system if it is not in continuous contact with the conductor wire. Radio tests made when the Lancaster–Heysham 6·6 kV scheme (50 c/s) first came into operation showed the presence of this type of interference, but the infrequent service and the fact that the collector characteristics would improve with use made the possibility of serious interference remote.

However, when the service became operational, a large number of complaints was received from viewers living within 250 yards (228·6 m) of the track. They experienced power line type of interference in Band I and the main source of the trouble was found to be sparking between the catenary wire and the heads of its 50-year-old supporting pin type insulators (now no longer used). Replacement of the insulators by a type with a metal head to which the catenary wire was clamped provided a permanent remedy.

No complaints of interference have been received during the 12 months that the 25 kV system involving Manchester, Crewe, and the Styal Loop has been energised. Tests on the 25 kV Colchester–Clacton Line, however, showed that where a combination of adverse conditions existed—industrial and coastal contamination of insulators, multiplicity of gantries, low television signal strength, and aerial pointing at railway—interference could be expected to an appreciable extent.

Signalling Power Supplies

All power supplies for signalling purposes must be derived from two substantially independent sources. Except at large and important centres where a prime-mover standby set is generally considered a justifiable investment, power is taken from a local source, usually in the vicinity of a track feeder or track sectioning cabin, and standby is obtained from the overhead lines.

Railway lineside telecommunications circuits have been designed to comply as far as possible with the directives of the C C I F and C C I T. Many of the railway signalling and telecommunication circuits in the past either had earth returns or were possibly d c two wire circuits with a centre earth connection, making use of polarised lines. With the new electric traction this type of circuit became impossible and various types of cabling circuit had to be adopted. In view of the fact that present electrification is on main lines and lines with intense suburban services, the older types of circuit had already been eliminated by colour light signalling, the block telegraph being replaced by train describers and continuous track circuiting.

The various types of cables used for railway telecommunications were described in detail in a paper (No 41): 'Railway Telecommunication Cables and Equipment', by D. R. Turner, of the British Transport Commission. All cables embody copper conductors and although only paper-insulated air-spaced cables have been used as yet, polythene-insulated quads will be employed as well in the future. On main routes, coaxial tubes will be provided for long distance trunk telephone circuits.

British Insulated Callender's Cable Co Ltd supplied the cables for the Crewe–Manchester Line. A feature of this route is the use of a composite cable between Crewe and Stafford that consists of four coaxial tubes, four carrier quads (eight pairs) and eight pairs for repeater control purposes, together with one 54-pair local cable. The overall diameter of this cable is about 3 inches (7·62 cm). Pirelli-General Cable Works Ltd supplied the cables for the Colchester–Clacton route; Standard Telephones & Cables Ltd supplied the cables for the Glasgow suburban route.

INTERFERENCE SUPPRESSION METHODS

Manchester–Crewe	Heavily screened railway cables, booster transformers with rail return.
Colchester–Clacton	Unarmoured aluminium-sheathed railway cables. Booster transformers with return conductors.
London–Tilbury–Southend **Enfield–Chingford–Bishop's Stortford** **Chelmsford–Colchester**	Unarmoured aluminium-sheathed railway cables, booster transformers with return conductors.
Conversion	Lead and aluminium-sheathed unarmoured cable. Booster transformers with return conductor.
Glasgow Suburban	Medium screened railway cables. Booster transformers with return conductor.
Crewe–Rugby	Medium screened railway cables. Booster transformers with return conductors.
Rugby–Wolverton (via Weedon)	Heavily screened railway cables. No booster transformers.

The Railway Conference: Testing and Research

To assess the performance of the new electrification scheme, a comprehensive system of tests was called for. In a paper (No 2): 'The Application of the 50 c/s System as Proved by System Tests', by J. A. Broughall, of the British Transport Commission, and F. J. Lane, of Preece, Cardew and Rider (Consulting Engineers), the authors point out that, considered purely as an electricity supply network, a traction system is more complex than normal power supply since in a power supply transmission system the places at which the load is imposed are known and definite, whereas the load imposed in a traction supply system by the individual motive power units moves between one point of supply and another.

It is the aim of system tests to provide a practical basis for correct statistical assessment of all the factors involved, so that individual characteristics of the various components can be satisfactorily correlated.

Clearly, a system test programme involves the simultaneous recording of many quantities and requires the co-operation not only of all departments of the railway organisation but also of such other bodies as the power supply authority, the Post Office, and contractors and manufacturers.

The most important consideration in designing the equipment for the system tests was to avoid the errors and delays of manual recording. In a paper (No 13): 'Systems Tests: Evaluation of Results', by T. A. Eames and G. H. Hinds, of the British Transport Commission, it is pointed out that the immediate need was for automatic equipment that would translate instrument readings into computer language. Punched tape was selected because of its higher punching speed compared with cards and because the B R Research Computer which was to be used in the first instance accepts this form of input.

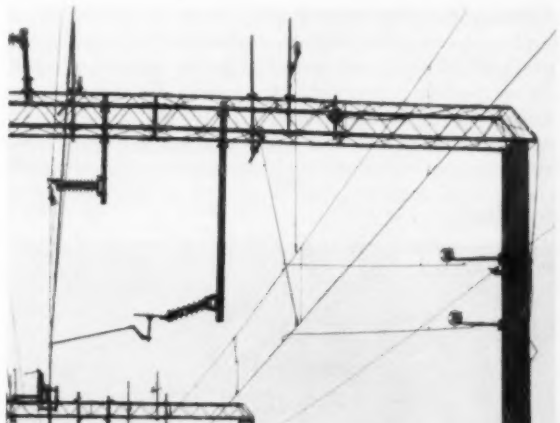
The sampling interval was thus dictated by the effective speed of the punch—about 25 characters per second. As an accuracy of three significant decimal figures was required, a sampling speed of six quantities per second was decided on. This is so much slower than the traction supply frequency that waveforms or short transients could not be handled, and only average values were dealt with. To ensure a common time scale throughout the system, the recorders were synchronised to supply frequency.

The electronic digital recorder developed was described in a paper (No 12): 'System Tests: Instrumentation and Measurements', by W. J. Webb, of the British Transport Commission, and W. Woods Hill, of Microcell Ltd (the company that built and designed it).

On a typical test in a multiple unit train, the recorder was used to log line voltage, line current, power, speed, and position. At railway signalling and telecommunications test sites it was used to log longitudinal induced voltage in unscreened signal cable (two routes), longitudinal induced voltage in screened audio signal cable (four routes), longitudinal weighted noise voltage (psophometer), transverse weighted noise voltage (psophometer), rail to earth voltage, rail to rail voltage, and signal supply voltage.

For waveform analysis a new instrument developed by the Post Office and made by the Telephone Manufacturing Co Ltd was used. It is provided with indicating meters but also feeds through a translator for recording by an electronic digital recorder. The fundamental and 11 selected odd harmonic components of 50 c/s voltage or current are measured and displayed simultaneously by the equipment, which is transistorised throughout. At its most sensitive setting, full scale deflection is produced by 100 mV of fundamental and 10 mV of each harmonic.

The computer most readily available for processing the data tapes is an Elliott 402F computer located in the Research Department at Rugby. In terms of data processing on the scale envisaged, the total storage capacity—about 5 000 locations of 32 binary digits—is not great. It was therefore decided that, to reduce storage and sorting within the machine, the use of the computer should in the first instance be confined to calculating the subsidiary quantities that could be derived from the 12 individual readings in one two-second section of tape.



Rotary potentiometers used for measuring uplift and lateral blow-off of catenary and contact wire

On a typical day's testing on the Colchester–Clacton line, with three test periods each of one hour, 17 E D Rs were in operation: eight on multiple unit trains, five at power supply stations, two at booster transformers, one at a railway signalling and telecommunication test site, and one at a G P O test site. The first analysis to be undertaken will be to determine the magnitudes and times of occurrence of the real peaks in the interference voltages induced in the rail and Post Office signalling cables, and the positions of the multiple unit trains and the magnitudes of the electrical quantities in them at the corresponding times. This analysis is still proceeding.

Research

The outstanding feature of railway electrification is the large amount of capital involved. This presents a two-fold challenge to the research worker: first, to devise means that will assist the fullest possible utilisation of the asset created by electrification and second, to do what he can to reduce the capital cost of further electrification. An outline of the directions in which research efforts are proceeding was given in a paper (No 11): 'Research for A C Traction', by F. T. Barwell, of the British Transport Commission.

Adhesion has been the subject of much investigation which is being continued by the Chief Electrical Engineer's Research Section. The basic causes of friction are not yet beyond the range of controversy, so that a solution of the problem presupposes an advance of knowledge of a fundamental kind. Nevertheless, sufficient progress has been made to enable tentative theories to be advanced to explain the observed behaviour and for remedies to be suggested which show promise in preliminary trials.

Closely bound up with the adhesion coefficient available between wheel and rail is the design of motive power capable of using this to the full. In certain circumstances, though not in others, the coefficient of resistance falls off rapidly as the relative speed of the rubbing surfaces increases. This obviously represents a very unstable situation if the characteristics of the motive power are such that torque does not fall off rapidly with increasing speed. The consequences of uncontrolled slip may be so serious, even resulting in the bursting of armatures, that anti-slip relays have been used for a number of years. But evidence exists that the catastrophic falling-off of the coefficient of friction occurring when slip takes place is preceded by a region in which friction increases with relative sliding. If torque could be so regulated that the critical value of relative sliding were not exceeded, better use could be made of the adhesion potential of locomotives. Work on these subjects is proceeding.

A general view of the railway traction research laboratory established by the B I C C Group

An investigation of commutation is in progress in a programme run jointly by the B T C and the electrical manufacturing industry. One aspect of the B T C's work has been the development of a low temperature radiation pyrometer to enable commutator surface temperatures to be measured in normal service.

At the other end of the motor scale, the complete absence of any need to provide a conduction path to the armature of an induction motor indicates that a very robust, reliable and maintenance-free motor could be constructed on this principle. To operate satisfactorily, however, it would have to be fed with polyphase current of variable frequency. Weight-penalty costs of rotating machinery to carry out this task dictates against its use, but new devices such as semiconductor inverters may change the picture.

Semiconductor devices also hold considerable promise in control circuits, where they could replace mechanical contactors. They also make possible more sophisticated methods of control; provision of anti-slip control, for example, would be much simplified.

As far as overhead equipment is concerned, medium-speed photography (100 to 200 frames a second) has been shown to be a useful means of studying the behaviour of pantographs mounted on vehicles actually in service. Study of the dynamics of overhead equipment has also been facilitated by the use of potentiometric transducers. The problem of isolating these from the supply voltage has been solved by the use of resin-bonded glass-fibre reinforced tubes.

The Problem of Restricted Overhead Clearance

The practical problem of accommodating the high tension overhead cables in situations where clearance is severely limited, notably in certain existing tunnels and bridges, was discussed in a paper (No 14): 'The Consulting Engineer's Contribution to 50 c/s Electrification', by E. L. E. Wheatcroft, of Merz and McLellan (Consulting Engineers). The British Transport Commission has laid down a static distance of 11 inches (28 cm) for 25 kV as the minimum permissible dimension between contact wire and the soffit of the bridge. There is a number of bridges, unfortunately, where it has not been possible to raise the bridge or to lower the track to meet this minimum requirement, and for such cases it was suggested that dimensions lower than 11 in (28 cm) could be permitted if a suitable form of solid insulating material could be interposed between the wire and the bridge.

An electrostatic shield, a silicone rubber sandwich, and butyl rubber secondary insulation were three solutions investigated, and the last has been adopted on the Colchester–Clacton–Walton line for a particular bridge. In this design there is no electrical connection between the contact wire and the solid insulation, and the air gap is subjected to a slightly higher stress than would occur without the presence of solid insulation. Nevertheless the air stress under the normal 25 kV is quite low and sparkover to the solid insulation will only occur under short-time transient conditions, such as perhaps during the passage of a steam train or during switching or lightning overvoltage conditions. High surface resistance is incorporated in the rubber so that if the air gap breaks down, the current is limited and the sparkover is not followed by a power arc.

In the bridge that has been equipped in this manner, the butyl rubber is 0·41 inch (1·02 cm) thick and is reinforced by steel plates that are arched for mechanical rigidity. It seems fairly certain that low bridges of up to about 39 feet (12 m) in length can be satisfactorily insulated in this way, the limiting dimension of 11 inches (28 cm) being approximately halved.

The Railway Conference: Future Locomotives and Trains

THE current plans for further electrification do not require any more deliveries of locomotives until about 1963/4. There is time, therefore, to assess the performance of the variations deliberately introduced into the initial fleet and to re-assess some of the parameters which controlled its design. Final re-assessment must necessarily depend upon experience of some duration in intensive service, but already certain trends are emerging.

In a paper (No 23): 'Locomotives and Multiple Unit Trains under Development', by J. A. Broughall and E. S. Cox, of the British Transport Commission, the features that were standardised in the initial designs are confirmed as giving satisfaction. At present little reason can be seen to vary them.

Serious consideration is being given to the use of axle-hung motors in place of the fully suspended motors adopted for the initial fleet. Although the evidence is not yet available in a form suitable for reporting, base-plate tests in progress suggest that the reactions on the track due to the axle-hung motors are less unfavourable than has been generally supposed. The simplest solution of using two axle-hung motors in each bogie may well prove to be the best.

Electrical equipment will still include rectifiers for converting from a c to d c, and there is a strong case for the incorporation of a rheostatic brake. This does not necessarily involve the use of semiconductor rectifiers, but the saving in space and weight which they offer is considerable. Experience to date suggests that they are likely to be preferred to mercury arc rectifiers.

A new development in hand is the construction of high-speed multiple unit train sets for the Liverpool Street-Clacton main line. They will include silicon rectifiers made by the Westinghouse Brake & Signal Co Ltd as sub-contractors to the General Electric Co Ltd who are making the complete electrical equipment. With all seats occupied, the maximum axle load is 14·5 tons (14 732 kg) and the maximum service speed is 100 mile/h (160 km/h). Balancing speed on level tangent track is 90 mile/h (145 km/h) and the journey from Liverpool Street to Clacton—70 miles (112 km)—will take 20 per cent less time than the present steam timing.

Three developments by the English Electric Co Ltd are illustrative of trends in electrical control. The fifteenth 3 000 h p locomotive of the series E3024/35 and E3303/5 will be equipped with air-cooled silicon diodes and will have a novel low-tension tap-changing scheme using transducers connected in such a way as practically to eliminate arcing at the tap changing contacts and to allow the possibility of smooth control of motor voltage. The 112th motor coach equipment for the London-Tilbury-Southend lines incorporates air-cooled silicon rectifiers and a novel tap-changing scheme using a stepless regulator manufactured by Brentford Transformers Ltd to give smooth control of traction motor voltage. In addition, a prototype equipment has been built and proved on the test bed for another form of notchless control in which rectifier switching during tap changing relieves the tapping contactors of arc rupturing duty, thereby reducing wear and maintenance and eliminating tap changing reactors, improving power factor during notching.

PRINCIPAL CHARACTERISTICS OF THE LOCOMOTIVES

Maker		**A E I (Rugby)**	**A E I (Manchester)**	**B R/A E I**	**G E C**	**E E**
Loco Nos		**E3001-23**	**E3046-55**	**E3056-95**	**E3036-45**	**E3024-35**
Total weight	(*tons*)	80·0	78·4	79·0	77·0	73·0
	(*kg*)	81 284	79 658	80 267	78 235	74 171
Max axle loading	(*tons*)	20·9	19·6	19·25	19·4	18·3
	(*kg*)	21 235	19 914	19 558	19 710	18 593
Weight of electrical equipment (with drive)	(*tons*)	39·6	37·7	39·0	38·0	37·0
	(*kg*)	40 235	38 303	39 624	38 608	37 592
Weight of two bogies (excluaing motors and drives)	(*tons*)	21·0	21·0	21·0	21·0	19·5
	(*kg*)	21 336	21 336	21 336	21 336	19 812
Weight of underframe and body	(*tons*)	19·4	19·7	19·0	18·0	16·5
	(*kg*)	19 710	20 016	19 304	18 288	16 764
Tractive effort for acceleration	(*lb*)	48 000	48 000	48 000	48 000	40 000
	(*kg*)	21 772	21 772	21 772	21 772	18 144
Continuous ratings at wheel tread at 22·5 kV and half-worn wheels						
Tractive effort						
Full field	(*lb*)	20 000	20 000	20 000	21 000	20 000
	(*kg*)	9 071	9 071	9 071	9 525	9 071
Weak field	(*lb*)	17 000	17 000	17 000	17 500	15 260
	(*kg*)	7 711	7 711	7 711	7 938	6 921
Speed						
Full field	(*mile/h*)	60	62	60	54	55
	(*km/h*)	97	100	97	87	89
Weak field	(*mile/h*)	71	73	71	66	73
	(*km/h*)	114	117	114	106	117
Power						
Full field	(*h p*)	3 200	3 320	3 200	3 000	2 940
Weak field	(*h p*)	3 200	3 310	3 200	3 080	2 950
U I C rating	(*1h s h p*)	4 260	4 260	4 260	4 270	3 735

The Conference Banquet at Guildhall

THE climax of the Conference week was a banquet held in Guildhall in the City of London, at which the British Electrical and Allied Manufacturers' Association (BEAMA) and the Locomotive and Allied Manufacturers' Association (L A M A) were joint hosts to the delegates.

Viscount Chandos, the President of L A M A, was in the chair, supported by Sir Leslie Gamage, President of the BEAMA, and the principal guests were the Lord Mayor of London, Sir Edmund Stockdale, and the President of the Board of Trade, the Rt Hon Reginald Maudling, M P.

The toast of the Lord Mayor and Corporation of London and the Sheriffs was proposed by Lord Chandos, and the Lord Mayor in his reply underlined the value of international meetings between professional people for the promotion of goodwill and the preservation of mankind.

Iuternational Trade a Factor for Peace

Proposing the toast of 'International Co-operation', the President of the Board of Trade said that Britain had had a long experience with railways, which indeed it had given to the world, and this applied particularly to the locomotive building industry. It was not difficult to praise the work of conferences such as this in promoting international co-operation. Many disputes, indeed wars, arose from trading difficulties. To-day, the more trade flows, the more understanding and the more opportunities of maintaining peace between nations. International trade needs peaceful conditions.

He hoped the 'Six' and the 'Seven' groups of countries could get together and sweep away further barriers to international trade.

There must be, he continued, a recognition of the duty we owe to the less developed countries, especially in the field of technical assistance and technical training. Railways throughout the world had transcended political barriers and the spirit of comradeship between railway men all over the world had been one of the outstanding qualities of the profession.

The railways had set a great example in extending knowledge and help to others ; this Conference had tried to spread the knowledge of electrification, and he hoped it would also help to show what Britain could supply to the world. He paid a tribute to the work of the United Kingdom Railway Advisory Service (U K R A S) and was glad to know that the next President of U I C would be a member of the British Transport Commission, Mr John Ratter.

Monsieur M. Dargeou, Vice-President of the I U R and Director-General of the S N C F, replied to the toast. Speaking in French, he expressed the gratitude and thanks of the overseas guests for the cordial welcome they had received. They had made excellent progress at the Conference thanks to the efforts of their hosts.

Railways, he said, had always been internationally minded, and as long ago as 1834 there was a plan to link the three kingdoms of England, France and Belgium. If the Channel Tunnel studies became effective they would do much to bring our countries closer together.

The 50 c/s electrification scheme was a great contribution to international co-operation. It had been developed in France and fostered by the joint use of techniques. The U I C with its membership of 50 administrations intended to continue its policy of close contact and collaboration, passing on its experience and techniques to any country that wanted them, and in so doing would help to open up new markets for European manufacturers. The results of the Conference would give great pleasure to all friends of Britain.

Lord Chandos, who proposed the toast of 'Railway Modernisation', stressed that the British Transport Commission was responsible for the largest network of railways anywhere in the world, and the size and complexity of the modernisation problem was almost unique. This was essentially a short-haul country and this brought its own problems.

British Railway Industry Serves The World

Manufacturers in this country worked in the closest liaison with the B T C. They had also played a leading part in the supply of equipment all over the world to a great variety of countries, and he would like everyone concerned to know that the British industry was willing to train any individual whom overseas administrations might wish to send to this country.

Replying to the toast, Sir Brian Robertson, Chairman of the British Transport Commission, said that there were very good reasons why this country was late in coming to electrification. One of them was the ravages of the war on this country, and particularly on the railways.

We must, he said, deal with first things first—the things which directly affected the services, the tracks and so on. The B T C owed an enormous debt to its suppliers in the industry, without whose help the Commission could not have achieved so much, and he paid a special tribute to the B T C's partners in the Conference and its hosts that night.

In saying 'Au Revoir' to the delegates, Sir Leslie Gamage said it was inspiring to have the final event of the Conference in the City of London's historic Guildhall. He thanked Sir Brian Robertson and his colleagues for the inspiration of the Conference—a great shop window through which we could show our goods to the world. In their visits to our factories too, he felt sure the delegates would have found that they compared favourably with any others in the world.

New equipment and processes

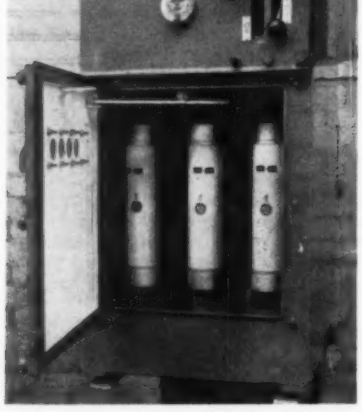
Extended Range of High-Voltage Switch-Fuse Units

Automatic high-voltage switch-fuses are an economical method of controlling and protecting distribution transformers, and very large numbers of Brush type HF11 units have been supplied during the last four years.

The Brush type HF11 high-voltage, switch-fuse unit is suitable for indoor or outdoor service and can be used singly or as part of a multi-panel switchboard, such as a ring main unit, in conjunction with fault-making oil switches. However, the size of transformer which could be protected by switch-fuse units has been limited to about 500 kVA at 11 kV by the current ratings of fuse-links available in this country.

A range of powder-filled fuse-links for use in air has now been produced by Line Equipment Ltd and their range includes ratings of up to 90 A at 11 kV and 125 A at 6·6 kV. These fuse-links have been tested to BS 2962, either at K E M A in Holland or at one of the A S T A stations in England. Not only were the top ratings certified (as specified in BS 2962) but in addition, certification tests were made at the lower current ratings. The fuse-links, which are of the current limiting pattern, consist of pure silver wire or strip (depending on the current rating) wound helically on carriers of ceramic material, surrounded by pure silica sand and contained in a ceramic barrel having copper end ferrules. A pilot fuse fed through the centre operates a striker pin which, in turn, actuates the switch-tripping mechanism.

The Brush switch-fuse unit has an air-insulated fuse chamber, a feature which is stated to give several technical advantages over oil-immersed types, and with the L E L fuses that are now available, can be used for protecting and controlling transformers of up to 1 500 kVA rating at 11 kV.



A Brush type HF11 switch-fuse, showing the LEL 90 A 11 kV fuses

These switch-fuse units and fuse-links have been tested in accordance with A S T A Publication No 22: 'Rules for the Short-Circuit Testing of Circuit-Breakers and Automatic Switches in combination with Electric Fuses and Fuse-Links'. All these tests, using 50, 70 and 90 A fuse-links for a rating of 250 MVA at 11 kV, were completely successful. In addition, heat run tests at the manufacturers' works have proved that the switch-fuse unit complies with BS 2962 in respect of temperature rise.

Short-circuit tests were also carried out at one of the A S T A stations to demonstrate the operation of the complete equipment to senior engineers of eight Area Boards of the C E G B and of the British Transport Commission. These tests also were completely successful. (*Brush Electrical Engineering Co Ltd*, Loughborough, Leics; *Line Equipment Ltd*, Bridgend, Glamorgan.)

Steel Thickness Gauge

Solus-Schall Ltd are marketing an 8 mm magnetic thickness gauge (Model 2211) which measures the thickness of steel tubes or steel plates. This equipment permits accurate and rapid identification of sound tubes or plates from those corroded beyond the limit of a specified safety margin.

The equipment, which is transportable and operates from battery or mains power supply, consists of a control unit and a magnetising probe. Operation is simple. The magnetising probe is held to the tube or plate to be tested, and when the magnetising push-button is depressed, steel thickness is shown on the meter. The control unit provides two meter ranges to measure up to 8 mm of steel thickness.

Model 2211 can be supplied with either hand or foot magnetisation control, and the firm also provide an inspection service using this equipment. The inspection service covers X- and gamma-radiography, as well as ultrasonic, penetrant and magnetic methods of non-destructive testing.

Details of the magnetic steel thickness gauge are: weight 30 lb (9 kg); size of control unit approximately 16½ inches (42 cm) wide, 9 inches (23 cm) deep and 7½ inches (19 cm) high. Power supply: 110/120 V or 200/240 V a c, or battery operated from built-in 12 V accumulators. (*Solus-Schall Ltd*, County Building, Honeypot Lane, Stanmore, Middx.).

Miniature Circuit Breakers

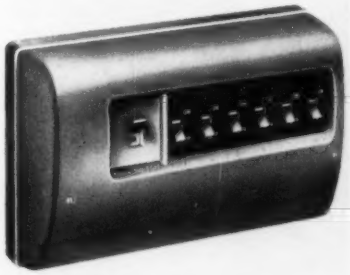
The Crabtree type C-50 miniature circuit breakers which were shown at the A S E E Exhibition in April of this year* are now in production and are generally available.

Designed to challenge the supremacy of rewireable or cartridge fuses for sub-circuit protection, these equipments represent a new development in an all-insulated consumer's unit embodying circuit-breaker protection for domestic installations. In addition, a range of sheet metal enclosures for both industrial and domestic installations is available.

The circuit breaker has an electromagnetically operated tripping mechanism and all ratings are set to trip at a maximum overload of 30 per cent. An essential feature is the built-in inverse time-current delay device which prevents harmless transient overloads from causing 'nuisance' tripping but ensures instantaneous tripping under heavy overload or short-circuit conditions.

Other features are that neither the minimum tripping current nor the nominal current rating are affected by variations in ambient temperature; that all current ratings maintain their accurate tripping characteristic after successfully clearing repeated overload or short-circuit faults, and that the trip-free mechanism ensures that the circuit-breaker cannot be held closed under fault conditions.

Type C-50 single-pole breakers are available in a range of ratings from 2·5 to 50 A; consumers' units and distribution boards are available in a range of types for surface or flush mounting and in 6-, 9- and 12-way patterns, and with or without a 60 A double pole isolating switch. (*J. A. Crabtree & Co Ltd*, Lincoln Works, Walsall, Staffs.).



This all-insulated consumer's unit is fitted with Crabtree C50 miniature circuit breakers

New Design of 500 V Switchgear

Under the name of 'Exel', M E M have introduced an ultra-modern range of 500 V switchgear which is a departure from the traditional pattern of industrial switchgear.

The new 'Exel' range incorporates front-operated switch handles which not only improve appearance but also allow more compact assembly on switchboards and panels. M E M 'Exel' switches and switchfuses are contained in fabricated cases of heavy gauge sheet steel with hinged covers, rustproofed and finished in grey stoved enamel, with chrome-plated front-operated switch handles.

The design complies with all relevant British Standards, I E E Regulations (13th Edition), and the requirements of the Electricity (Factories Act) Regulations.

The manufacturers point out that with the steadily increasing load in the large industrial areas of Great Britain, it is apparent that the point can soon be reached where the damaging effects of short-circuit fault current may exceed the rupturing capacities with which most semi-enclosed rewirable fuses are capable of dealing. It is

* THE BEAMA JOURNAL, **67**, No 2, p 56

for this reason that in all M E M's new 500 V switchgear and fuseboards every unit will accept either a rewirable or an H R C fuse carrier. Now that a British Standard of Dimensions has been agreed for H R C cartridge fuse links in BS 88, Appendix 'J' Dimensions, all fuse-links so made will be interchangeable, and therefore eliminate much inconvenience.

'Kantark-Exel' H R C cartridge fuse-links for use with these ranges have been A S T A tested and certified for Categories of Duty 440 AC5 (46 000 A), 440 AC4 (33 000 A) and 440 AC3 (16 500 A).

Another established M E M range—the 'Memrex-Senior' weatherproof switchgear in cast iron cases—has been redesigned embodying new improvements. Side-operating switch handles are retained, but all units are now fitted with 'Kantark-Exel' fuses of rewirable H R C pattern, the latter again designed to accept H R C cartridge fuse-links to BS 88, Appendix 'J' Dimensions. (The *Midland Electric Manufacturing Co Ltd*, Reddings Lane, Birmingham 11.)

'Memrex-Senior' 1 360 A triple pole and neutral switch. The cast iron case is weatherproof and dustproof

Distance Protection Scheme for Distribution Lines

A new low cost switched Mho distance scheme for the phase fault protection of 11 kV and 33 kV distribution lines is announced by *English Electric*. Contained in a single case measuring only 20 by 6 by 6 inches (50·8 by 15·2 by 15·2 cm) it costs little more than directional overcurrent protection.

Inverse time-overcurrent relays have for long been the standard form of protection for distribution lines because of their simplicity and low cost. They are however becoming inadequate on increasingly complex lines for the discrimination and rapid clearance of faulty feeders. Distance protection will overcome these difficulties by providing good discrimination, short operating times and back-up protection.

The design of the overcurrent starters on this new unit gives an effective pick-up/drop-off ratio of 100 per cent, which allows fault settings to be close to full load. Correct zone and phase indication is ensured by a simple interlock which operates only when the relay trips.

The new scheme, denoted type SSM3V, uses standard relay units and is simple to apply. The operating principle is as follows. A single admittance (mho) relay (type YCG) is used to measure the distance from the relaying point to the fault. It is connected to the faulty phases by instantaneous overcurrent starters (type CAG) through auxiliary relays.

Three zones of distance measurement are provided by the Mho relay. Tripping occurs when the impedance from the relaying point to the fault is less than the ohmic reach of the relay. A timing unit is used to increase the range of the Mho relay from zone 1 to zones 2 and 3 after successive time intervals. The operating time required for zone 1 is approximately 0·1 second. (*The English Electric Co Ltd*, English Electric House, Strand, London, WC2.)

Tropicalised Shaded Pole Motor

B V C Electronic Developments Ltd, who are well known for the manufacture of miniature precision electric motors, have now introduced a new low-priced shaded pole motor, produced to a much more stringent specification than is normally associated with equipment of this type. This motor is fully tropicalised to operate in virtually any weather conditions, and has been specially designed to meet the requirements of the British Ministry of Aviation's specification DTD 1085/B.

The makers state that this model meets many requirements for which more expensive types are normally employed. Typical applications are for fans and actuators and it is already being supplied for driving mixers in corrosive atmospheres in the chemical industry, for cooling apparatus on television cameras and for use in several types of electronic computors.

This motor is continuously rated (without air stream cooling) at 12 W with 2 W output, and operates on mains voltages of 115 and 230 V to a maximum of 2 700 rev/min. A 50 W version with an output of 12 W is also available for use where more power is required. (*B V C Electronic Developments Ltd*, Goblin Works, Leatherhead, Surrey.)

Dielectric Heating Generator

A new 6 kW dielectric heater is announced by *Pye Ltd*. It has been designed for continuous operation and incorporates the latest design techniques. The generator has a high impedance output and is suitable for heavy duty work and the rapid curing of synthetic resin adhesives in the woodworking industry. Among its many applications are the lipping of flush doors and of chipboard, the making of laminated shapes, and the edge-jointing of timber.

The oscillator valve may be either air-cooled (type RF 12/A) or water-cooled (type RF 12/W) depending upon customer's requirements.

Because of its simplicity of operation it can be used without difficulty by unskilled labour. The controls, indicator lamps, anode current meter and process timer are conveniently grouped on the front panel, and compact design allows the equipment to occupy the minimum of floor space. The makers claim that it is extremely dependable in operation as a result of advanced design and the use of components of proved reliability.

The generator requires a 3-phase mains supply and operates at 13·56 Mc/s (international ISM band) and is complete with remote display unit. Overall height is 61 inches (155 cm), width 25½ inches (65 cm) and depth 23½ inches (60 cm). (*Pye Ltd*, Process Heating Division, 28 James Street, Cambridge.)

The 6 kW dielectric heating generator produced by Pye Ltd

New EMI '3-D' Television

An advanced system of stereoscopic closed-circuit television has been developed by *EMI Electronics Ltd* to meet the requirements of nuclear plants and other establishments where dangerous materials have to be manipulated remotely.

EMI's stereoscopic equipment utilises the company's standard closed-circuit units and consists of two camera channels mounted side-by-side and arranged to relay pictures on to two monitors. The pictures from these are then superimposed on each other, by means of a mirror and polarised glass, to form a single image.

When viewed with polarised spectacles this produces a realistic three-dimensional picture. The equipment has already been demonstrated in Great Britain and some European countries, and is stated to have proved highly successful in practical demonstrations.

Features claimed for the EMI system include the simplicity with which it can be set up and controlled, and the novel arrangement by which the human eye's 'angle of squint' has been realistically achieved by mechanical means. (*EMI Electronics Ltd*, Hayes, Middx.)

Book Reviews

The Performance and Design of Direct Current Machines. *By A. E. Clayton and N. N. Hancock.* $8\frac{1}{2} \times 5\frac{1}{4}$ *in* (222 × 146 *mm*). *Pp xx* + 516. *Illustrated. Index.* (*London: Sir Isaac Pitman.*) Price 40s net.

The third edition of this well-known textbook on direct-current machines was fortunately in the final proof stage before the unfortunate passing away of Dr. Clayton. Since the first edition was issued in 1927, the MKS μ system of units has been standardised for instructional purposes in this country. The author took, with the aid of Mr Hancock, the opportunity in revising the original text to base it on the new unit system, rewrite the chapter on electrical insulation in the light of modern knowledge, modernise the machine illustrations, and also add a chapter on the eddy-current losses in deep armature conductors. In addition, other modifications and changes in the text have been made, such as a fuller treatment of duplex windings due to their increasing importance in large dc machines.

The general presentation of the topics covered in the text of twenty chapters, illustrated by 314 diagrams and figures, is otherwise very similar to that of the original edition. The book is essentially a book for the student of electrical engineering, and only presupposes a small knowledge of electrical engineering principles. It is suitable for the second year undergraduate and diploma courses, and for courses leading to the Higher National Certificate in Electrical Engineering.

There are 167 examples collected together, with answers to the numerical questions, at the end of the book, by means of which the reader can test the progress he is making in his studies.

The first thirteen chapters deal with the general principles and performances of direct-current machines, and this is the part of the book which will be of the utmost value to students. The other seven chapters are more concerned with design of the d c machine, and this is nowadays of less importance to undergraduate students.

The book is well printed and attractively produced. It is well written, easily read and is an excellent presentation of a very important, but often neglected, subject. It is well recommended.

P. F. SOPER

The IEC Tracking Test. Design of an Automatic Tracking Comparator. *By N. Parkman. Report No. L/T388.* $9\frac{7}{8} \times 7\frac{7}{8}$ *in* (250 × 200 *mm*). *Pp* 18. (*London: The British Electrical and Allied Industries Research Association*, 1959.) Price 7s 6d net.

The details of the new international test for tracking are outlined and discussed. An automatic apparatus for implementing the test, suitable for use in industry, is described. The use of this apparatus, originally constructed for research purposes, is considered more practical than the manual method envisaged by the International Electrotechnical Commission (IEC), and can be used to reduce the tedium and cost involved in a lengthy routine test.

Analysis of Deformation. Volume 4 (Waves and Vibrations). *By Keith Swainger.* $8\frac{1}{4} \times 5\frac{1}{4}$ *in* (222 × 146 *mm*). *Pp xxvii* + 370. *Illustrated. Index.* (*London: Chapman & Hall.*) Price 75s net.

The new volume in this monumental work on deformation is concerned with waves and vibrations and in it the author describes their propagation through and on the surface of substances (regarded as continua) possessing such physical properties as elasticity, plasticity and fluidity separately or in combination. He gives, first, the generally accepted classical approach to each phase of the study and follows this with an account of applications of his own theories and, where deemed necessary, a critical appraisal of diverging views. This has been the general pattern of the previous volumes.

Chapter 1 is introductory and serves as an outline to guide the reader in the matter of the fundamentals of those matters that are discussed subsequently in considerable detail. Chapter 2 deals with classical mathematical theories to analyse continua. Chapters 3, 4, 5 and 8 relate to the propagation of waves through substances of restricted isotropy, namely and respectively: elastic solids, fluids, plastic solids, and viscoelastic solids. Chapters 6, 7 and 9 are concerned with surface waves on substances of restricted isotropy, being respectively elastic solids, fluids, and viscoelastic solids.

The final chapter 10 applies the author's theories to geophysics, discussing for example volcanoes, earthquakes, mountains and the earth's density. Herein, a unified mechanistic theory is presented of the cause of earthquake waves, volcanoes and the crustal features of the earth; the formation of craters of the moon, and the cause of sunspots. There are seven mathematical appendices, a lengthy list of references, and author and subject indexes.

The manner of presentation in this book is the same as in the three previous volumes,* it is mainly mathematical through the medium of vector and dyadic algebra. It is one that lends itself admirably to the purpose, as all four volumes show.

There are no doubt some who have not found it possible to accept the author's views as recorded in the earlier volumes, but as his studies reach their conclusion (two further volumes will complete the work) we believe there will be a substantial reassessment of the importance of Dr Swainger's work and, we hope, an acknowledgement of its soundness.

The type setting, printing and format of the book are a sheer delight—as were the others.

S. AUSTEN STIGANT

* THE BEAMA JOURNAL, **62**, No 4, p 166; **64**, No 2, p 89.

The Theory and Design of Inductance Coils. *By V. G. Welsby.* $8\frac{1}{4} \times 5\frac{1}{4}$ *in* (222 × 146 *mm*). *Pp* xviii + 232. *Index. Illustrated.* (*London: Macdonald & Co*, 1960.) Price 30s.

When this book was first published, ten years ago, the author must have been the subject of thanks from many engineers, particularly those in the telecommunications field who have to design coils possessing the prime requisite of inductance, but which in some cases must have other characteristics as well.

Previously there had been much 'rule-of-thumb' procedure, but Dr Welsby swept it all away by collecting in one book proved techniques based on scientific principles.

The second edition of the work aligns the contents with the developments of the past ten years, and it can be well recommended as an essenital volume for all engineers who have to design inductance coils.

The chapters cover Fundamental Theory; Equivalent Circuits of Inductance Coils; Air-Cored Coils; Design of Stranded Wire for Coils; Coils with Laminated Iron Cores; Coils with Dust Cores; Coils with Ferrite Cores; Self-Capacitance of Coils; Q_0-Frequency Curves for Air-Cored Coils; Q_0-Frequency Curves for Coils with Ferromagnetic Cores; and Impedance Measurements.

The book concludes with six worked examples of coil design and a bibliography.

J. H. J.

The Elements of Determinants, Matrices and Tensors for Engineers. *By S. Austen Stigant.* $8\frac{1}{4} \times 6$ *in* (222 × 152 *mm*). *Pp xi* + 433. *Illustrated. Index.* (*London: Macdonald.*) Price 60s net.

Most engineers are well-versed in the standard method of solution of a set of linear equations, but very much less acquainted with the subject of matrices, and still less informed on tensors. This is notwithstanding the fact that the use of matrix or tensor techniques has been accepted as simplifying the solution of a wide range of engineering problems, as distinct from superficial problems that can readily be solved by other methods. What has been needed for a long time therefore, and is now provided by this book, is a means by which an engineer with no knowledge at all of matrices or tensors, and with only a limited knowledge of mathematics, can start from the beginning with a revision of the solution of linear equations and determinants, and then proceed by means of very detailed and realistic problems to acquire the techniques that had possibly not been included in his university or technical college education. The treatment has deliberately been made elementary, but is authentic, and very few people could have been in a more suitable position to write on these subjects than the author, who is not only an eminent electrical engineer in this country, but also a joint-organiser of *The Matrix and Tensor Quarterly*.

After a brief introductory chapter on nomenclature, the book is divided into three main parts, dealing respectively with determinants, matrices and tensors. The first part comprises a description of the evaluation, structure, properties and mani-

pulation of determinants together with the solution of a set of equations. This is followed by a similar treatment for matrices, after which the remaining half of the book is devoted to tensors, some of the more advanced techniques of which are given in the form of appendices. Amongst the tensor work covered are the subjects of reference frames and axes, notation, variance and association, transformation, the Kronecker delta, actual and primitive networks, typical network examples, multiple transformation and orthogonal network. Each of the basic sections of the book is terminated by a bibliography.

One of the striking features is the wealth of detail with which each mathematical step has been recorded. The many worked examples in the text and examples for the reader (with answers) also help to make this a book that will be greatly liked by student, teacher and engineer alike. The book as a whole is a thoroughly worth-while project, well conceived and carried out, and it is to be hoped, as a result, that more people will take an interest in the subject matter which itself should be taught more regularly throughout the country.

H. GOLDENBERG

Electrical Who's Who 1960-61. 9 × 6 *in* (229 × 152 *mm*). *Pp* 566. (*London: Electrical Review Publications Ltd*, 1960.) Price 35s net.

This is the sixth edition and the tenth year of publication of this excellent work of reference.

The present edition contains some 9 000 entries of the people connected with the electrical and allied industries, each entry consisting of a brief biography of the person concerned with details of his training and career. In the case of authors and writers, the subject's published works are also included.

A classified index under the names of companies and other bodies also gives a ready cross-reference to the personnel of the organisation concerned.

This is a valuable reference book, particularly for readers overseas who have dealings with the British electrical and allied industries.

Inventions, Patents and their Management. *By Alf K. Berle and L. Sprague de Camp.* 8½ × 6 *in* (216 × 152 *mm*). *Pp* ix+602. *Index. Illustrated.* (*London: D. Van Nostrand Co Ltd.*) Price 94s.

'This book is planned to guide inventors in every aspect of their work and to teach them the language of invention. While we do not encourage inventors to try to act as their own patent attorneys, we do try to tell them how to proceed with their inventions in their early stages; how to choose a patent attorney; how to co-operate with him to get the most out of his services; how to read, understand and evaluate patents, and how to exploit inventions commercially.' There, concisely, is the object of this book and at the same time an implied warning not to regard it as a 'Do it Yourself' handbook; nothing is potentially more fatal to the value of Letters Patent than for an inventor to believe that 'every man is his own patent agent' and to act upon such a wrong belief.

The present book is a complete re-writing, with added material, of a book 'Inventions and Their Management' published originally by the same authors in 1937, and it brings the subject right up to date. It is an account of how these things are done in the U S A, and the guidance offered therefore is first to those residing in that country, and second to those domiciled elsewhere and who may wish to secure patent protection in the U S A. It is desirable that inventors in the second group mentioned should know that U S patent law and procedure differ from those in other countries, although the inventor's patent agent will ensure that the necessary documents are prepared and lodged in the correct form and manner.

In addition to being a very thorough guide on official patent matters in the U S A, the book provides a great deal of sound advice on more practical issues such as, for instance, patentability; choosing a patent attorney; studying the market and product; division of patent rights and income; selling a patent; royalty licences; exploitation of inventions, and infringement. There are also chapters on special classes of patents and foreign patents, trade marks (and designs), and copyright; an excellent bibliography listed under subject headings, a patents glossary, a very full index, and a list of law cases cited.

An attractive feature of the book is its sheer readability; it is nearly as much a study in humanity as of its title subject.

There is a great deal of money wasted on patents; that is, wasted from the point of providing adequate returns on money spent on so protecting the rights in an invention. Therefore, 'the inventor who knows the right procedure to follow, and the mistakes to avoid, saves himself much expense, grief, and time'. That, plus the advice of a qualified patent agent!

An excellent book, well recommended.

S. AUSTEN STIGANT

Photoconductivity of Solids. *By R. Bube.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp* xix + 461. *Illustrated. Index.* (*London: Chapman & Hall*, 1960.) Price 118s.

In listing as many as 1 009 references, covering the years 1873 to 1959, to papers, books etc published on various aspects of photoconductivity, the author provides ample evidence of the widespread interest that has been taken in the subject. It is therefore rather surprising that a book like the present one has been so long in making an appearance. This is no doubt due to the relatively modern recognition of the value of so-called solid state research, which has already provided the physicist with a far better understanding of the properties and behaviour of solid matter than hitherto. Photoconductivity is one of the branches of this research and the present work is offered as a comprehensive analysis of the subject.

In substance, the book discusses electron processes in crystals, photoconductivity processes, preparation of photoconductors, electrode effects, imperfection photoconductivity, energy bands and excitation transitions, free-carrier scattering and mobility, traps and trapping effects, recombination processes, theoretical viewpoints on photoconductivity, and various topics related to photoconductivity in general. A survey of uses of photoconductors is given in an appendix. The book is well illustrated and the mathematical content is but slight.

The intention of the author is to provide a unified physical description and interpretation of photoconductivity of phenomena in conductors, semiconductors and insulators, and this book is the first to accord the subject a comprehensive analytical treatment.

The book is intended for graduate physics students, for research workers in allied fields, and for the more advanced reader who requires a detailed treatment of current theory of the mechanism of photoconductivity and an account of particular phenomena which illustrate the variety of characteristics obtainable.

The book is an excellent account of the subject and can be highly recommended.

S. A. S.

Solid State Magnetic and Dielectric Devices. *By H. W. Katz.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp* xxi + 542. *Index. Illustrated.* (*London: Chapman & Hall.*) Price 108s net.

The growth of semiconductor engineering and physics during the past ten years has resulted in many new areas of interest for the electrical engineer. Generally there has been a strong association with single crystal germanium or silicon; in fact 'solid state' is often synonymous with these two materials. However, studies in solid state physics have resulted in a much better understanding of the magnetic and dielectric properties of materials, and the present work is a good survey from fourteen authors and contributors of the present frontiers of knowledge in the spheres of magnetics and dielectrics.

The opening chapters deal concisely with electromagnetic and electrostatic field theories, and with the electrostrictive and magnetostrictive systems that naturally follow. These lead to a chapter on non-linear magnetic and dielectric materials, with particular attention to their significance in switching systems.

The next six chapters cover a good deal of practical work that has developed from first principles, and include sections on electro-mechanical applications; small-signal applications; ferrites at microwave frequencies; magnetic and dielectric amplifiers; and digital techniques. A chapter on magnetic recording is particularly useful, as it deals more with the underlying magnetic theory rather than with recording systems. But the statement that there is a reduction from a magnetic recording with each playback should be qualified more explicitly, because every user of magnetic tape or drums knows that the effect is of no practical significance.

A final chapter on magnetic and dielectric measurements rounds off the book, and although the work suffers, in some respects, from being a compilation, it is an attempt to unify knowledge in a new field of physics, and as such must be recommended.

J. H. J.

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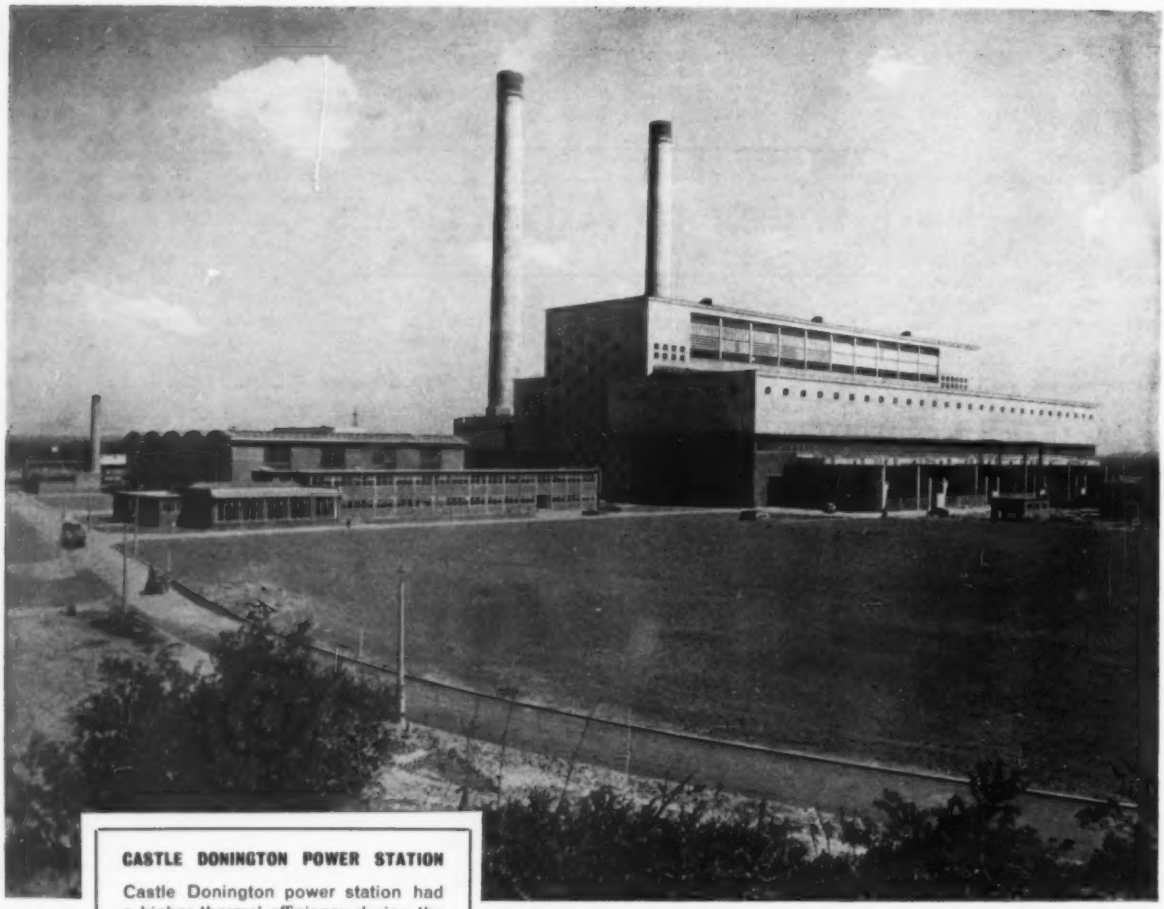

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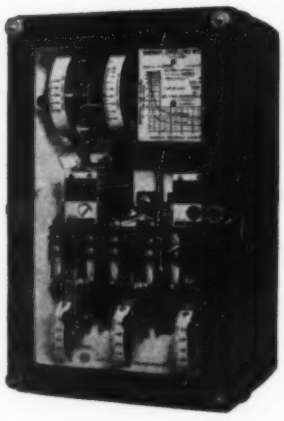

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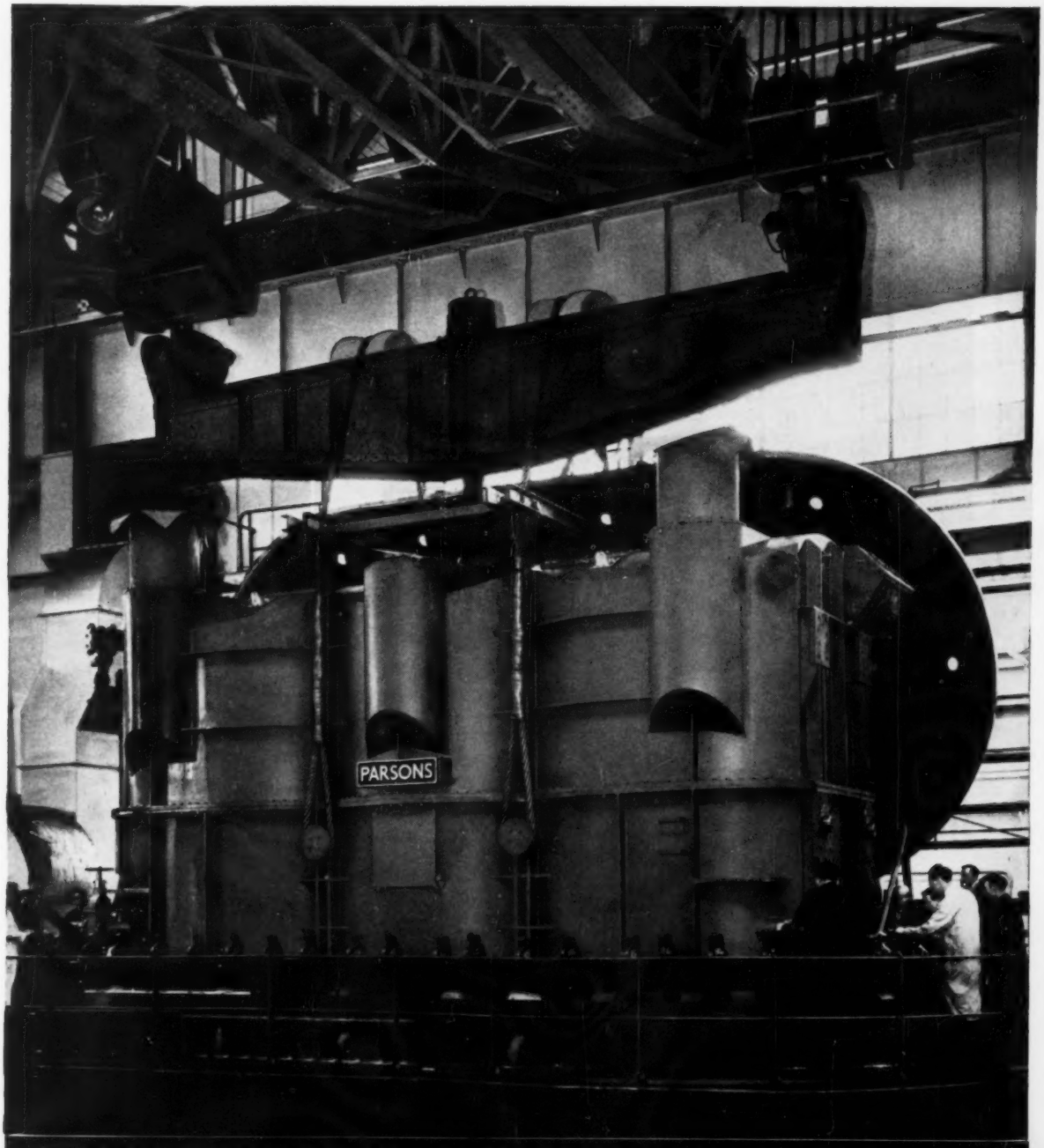

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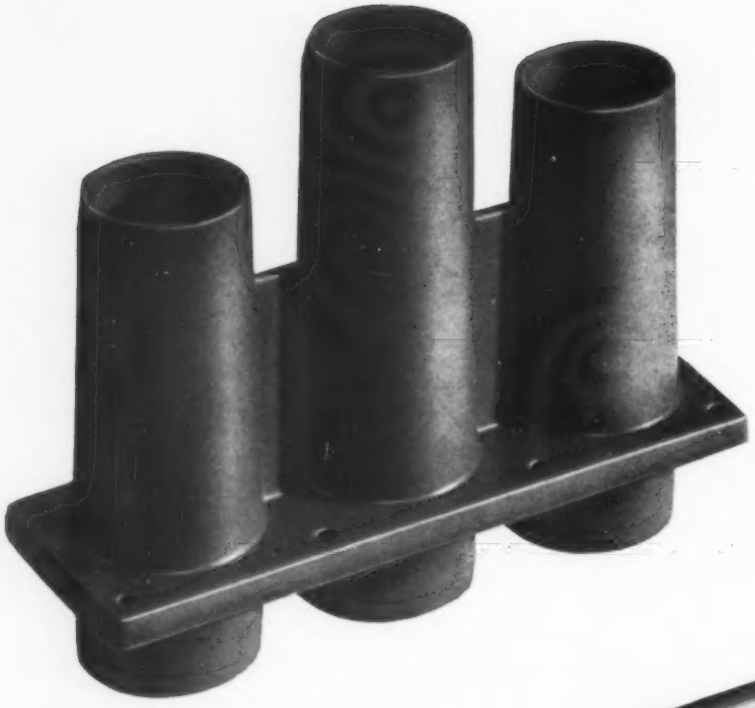

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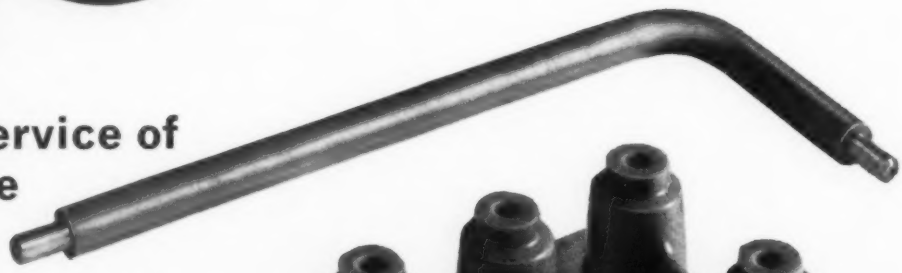

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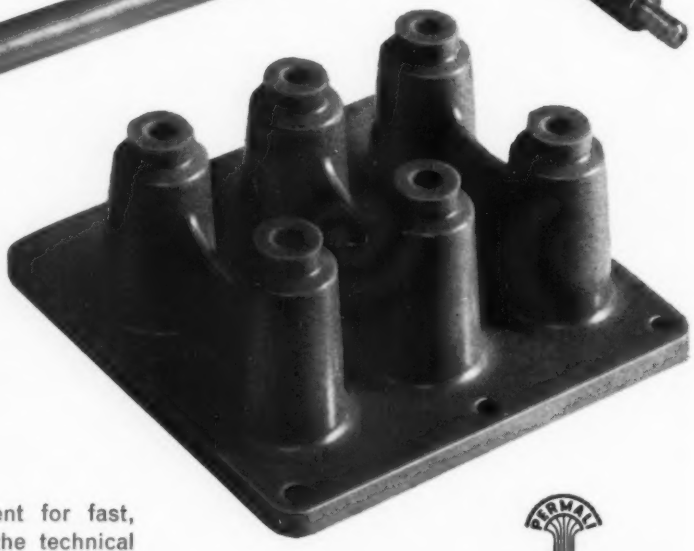

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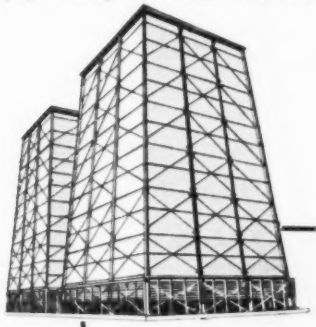

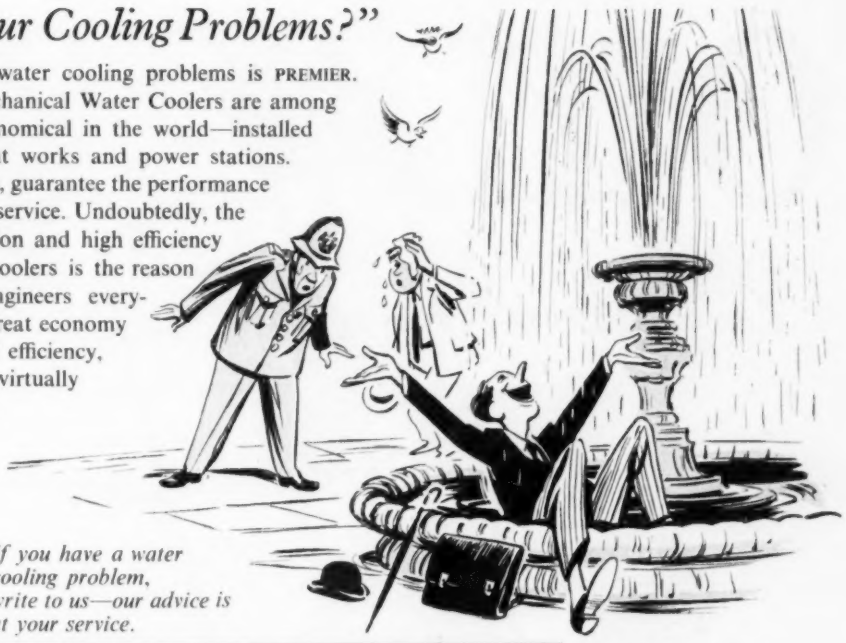

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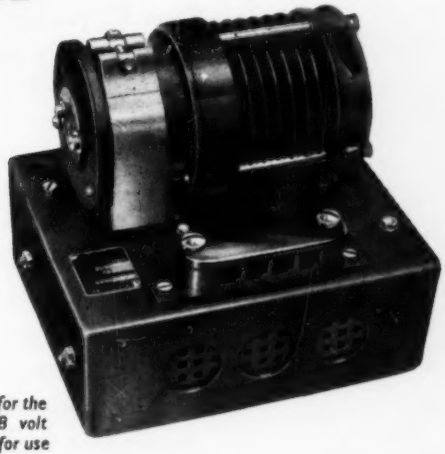

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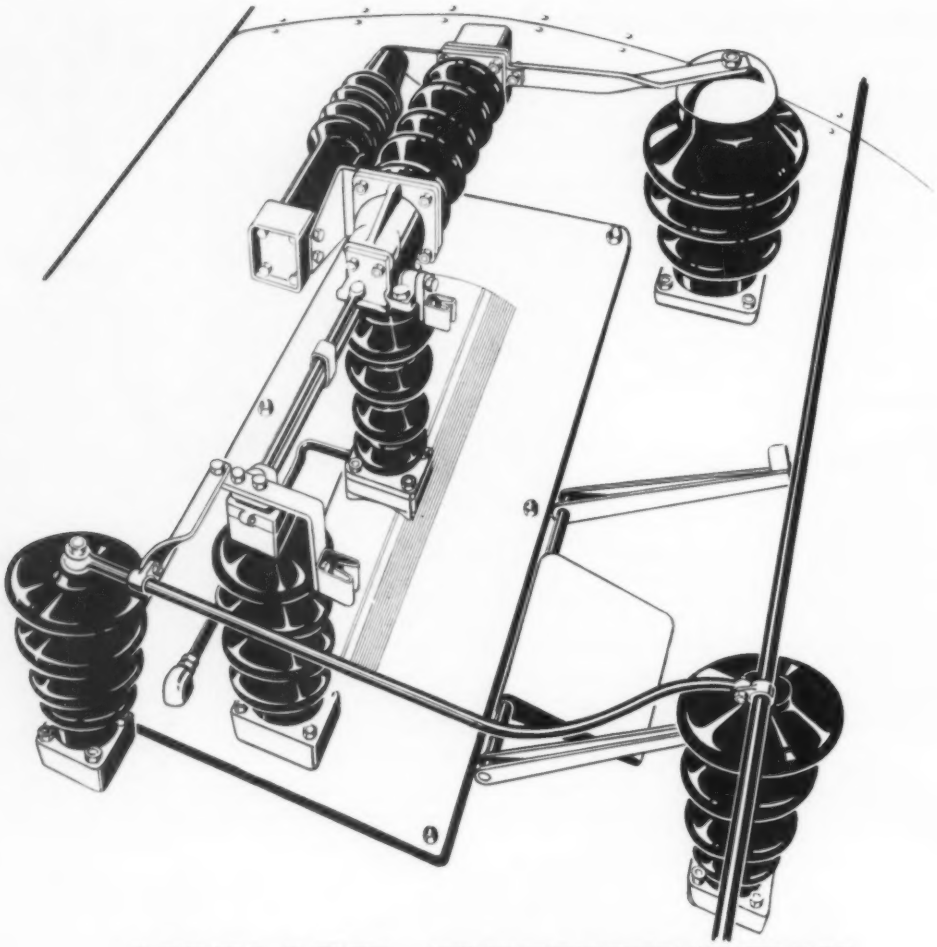

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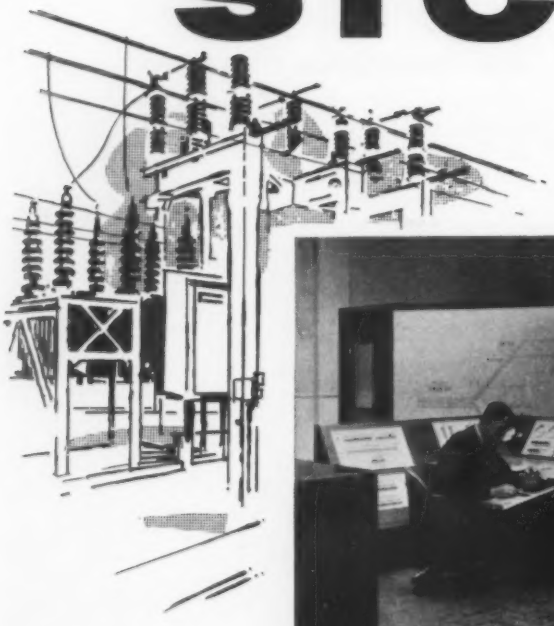

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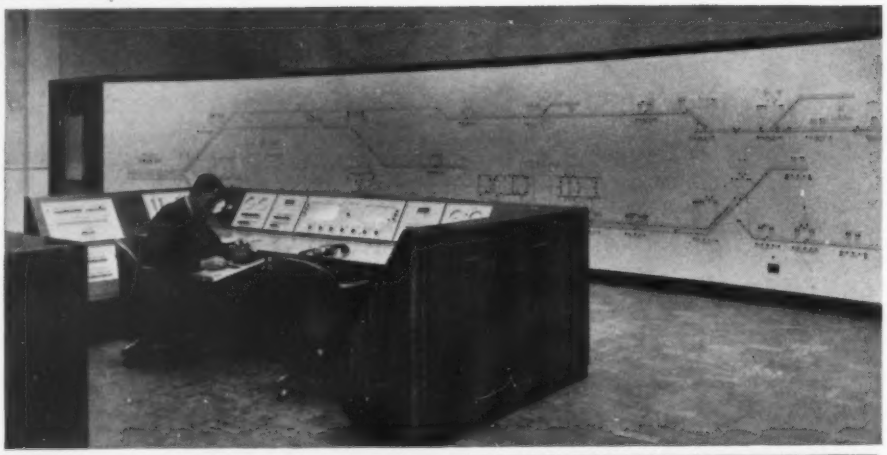

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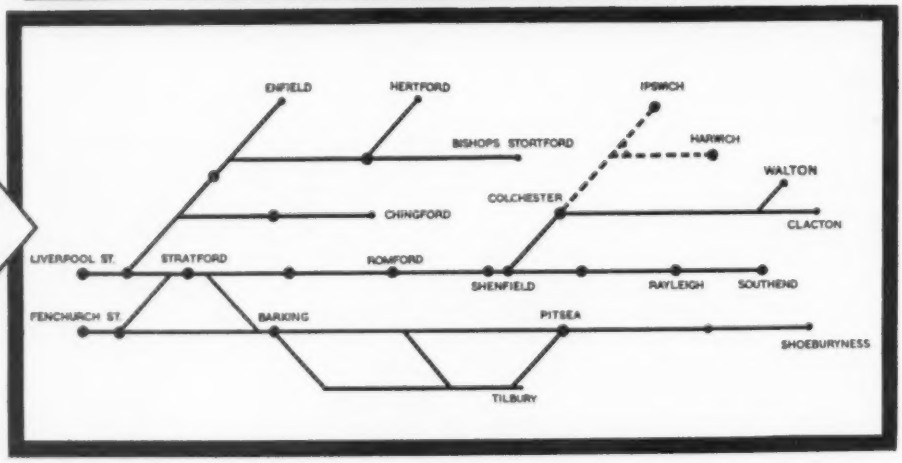

The map shows the routes concerned, and the control stations at Romford and Pitsea serving the Liverpool Street and Fenchurch Street schemes respectively. When the schemes are completed, approximately 45 remote stations will be controlled from Romford and 14 from Pitsea.

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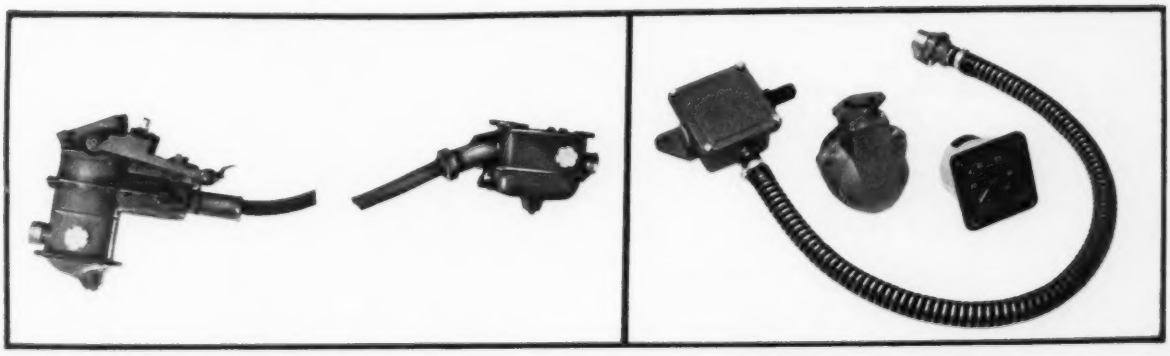
The Stone-Faiveley pantograph adopted by British Railways

Some important items of equipment specially designed for use in railway electrification schemes have been shown on our Stand, No. 16, at the British Railways Electrification Exhibition. They included Stone-Faiveley pantographs and intercoach couplers, Smith-Stone speed indicating and controlling equipment, the Stone Carriage Temperature Controller, and the Stone Battery charging unit that supplied the power for lighting the rolling stock on display. We shall be pleased to provide further particulars of any of these equipments on request.



Stone-Faiveley intercoach couplers

Smith-Stone speedometer equipment

J. STONE

& CO. (DEPTFORD) LIMITED

ARKLOW ROAD LONDON S.E.14

A member of the Stone - Platt Group of Companies

Magnet wheel of a G.E.C. 62,500 kVA hydro-alternator for Aura Kraftanlegg, Norway.

LAMINATIONS
of all types, in all sizes and in all grades of material.

FERROSIL
hot-rolled and cold-reduced electrical sheet and strip, and hot-rolled transformer sheet.

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cold-reduced oriented electrical sheet and strip.

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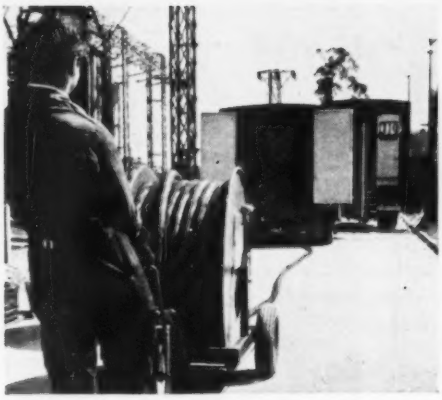
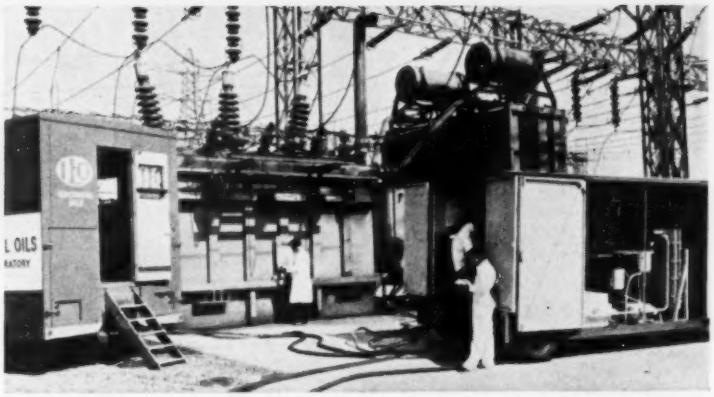
Enquiries for sheet and strip to be addressed to RICHARD THOMAS & BALDWINS (SALES) LIMITED, WILDEN, STOURPORT-ON-SEVERN, WORCS.
Enquiries for laminations to be forwarded to RICHARD THOMAS & BALDWINS LIMITED, COOKLEY WORKS, BRIERLEY HILL, STAFFS.

Our Cookley Works is one of the largest in Europe specializing in the manufacture of laminations for the electrical industry.

Treatment of electrical oils on site



1 Arrival on site of the ILOVAC and the laying out of its power cable for connection to supply.



2 The ILOVAC at work, drying the transformer by circulating super dried oil. The Mobile Laboratory, which controls the operation, is seen in the left foreground.

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The I L O Service is a complete and comprehensive one. It will guarantee the safe and efficient running of your transformers by keeping their insulating oil always in perfect physical and chemical condition. The Wakefield-Dick electrical engineers are always at your service. Their advice can be invaluable.

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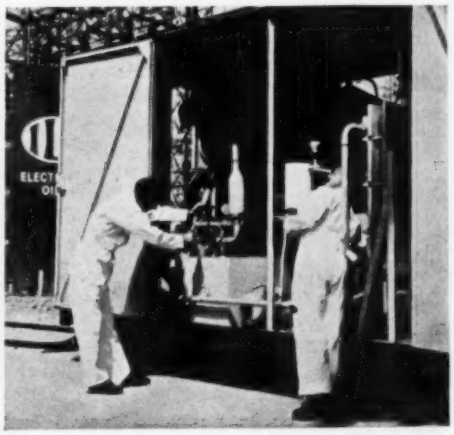


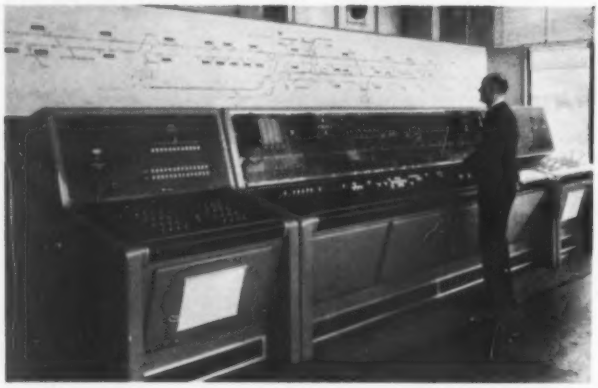
3 Two of the ILOVAC operators drawing samples of the treated oil for check tests in the Mobile Laboratory during treatment.

Co-operating in British Railways A.C. Electrification Programme . . .

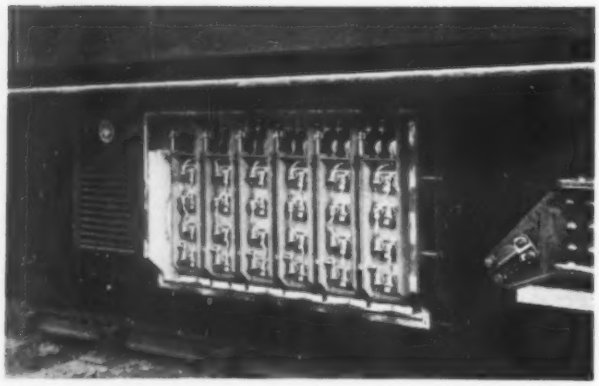
WESTINGHOUSE

BRAKES, SIGNALS, RECTIFIERS

The multiple unit trains built by British Railways at York and Doncaster for service on the Clacton–Walton–Colchester and the London–Tilbury and Southend Lines, are fitted with Westinghouse ELECTRO-PNEUMATIC BRAKES—the modern brakes that provide rapid acting control so necessary when fast passenger services are to be operated on a close schedule.



WESTINGHOUSE SIGNALLING designed for the A.C. Electrification plan is being extensively adopted. The picture shows the O.C.S. Control Panel in service at Sandbach, on the Sandbach–Wilmslow Control Area of the Manchester–Crewe main line, one of the many sections now operating, or under construction.



WESTINGHOUSE silicon main traction rectifier type 6029 rated at 1500 volts 508 amperes continuous for a.c. multiple unit stock on British Railways (Eastern Region) Enfield/Chingford services. 23 silicon main traction rectifiers of similar construction rated at 1250 volts 880 amperes have been ordered by General Electric Co. Ltd., for Liverpool Street/Clacton high speed Inter-City services, bringing the total capacity of Westinghouse Rectifiers for the B.T.C. a.c. multiple unit stock and locomotives to approximately 70MW.

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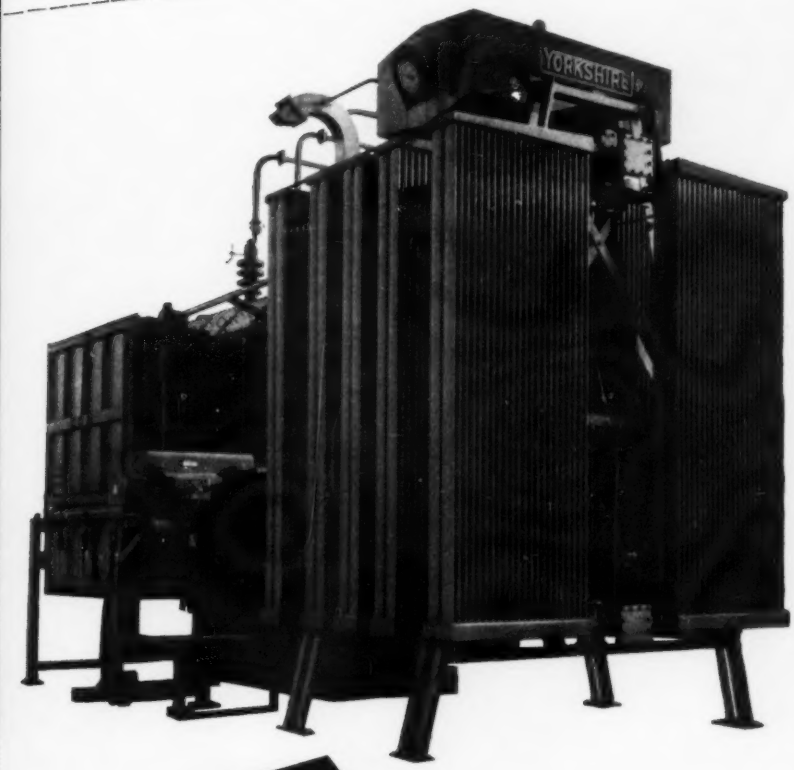

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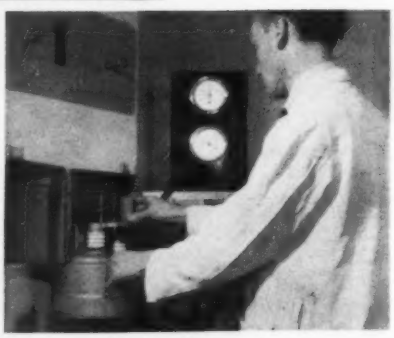
Yorkshire Imperial have supplied many millions of condenser and other tubes, and also condenser plates, for use in electricity generating stations in Great Britain and overseas, and consistently reliable, efficient and trouble-free service has been obtained from these products under a wide variety of operating conditions.

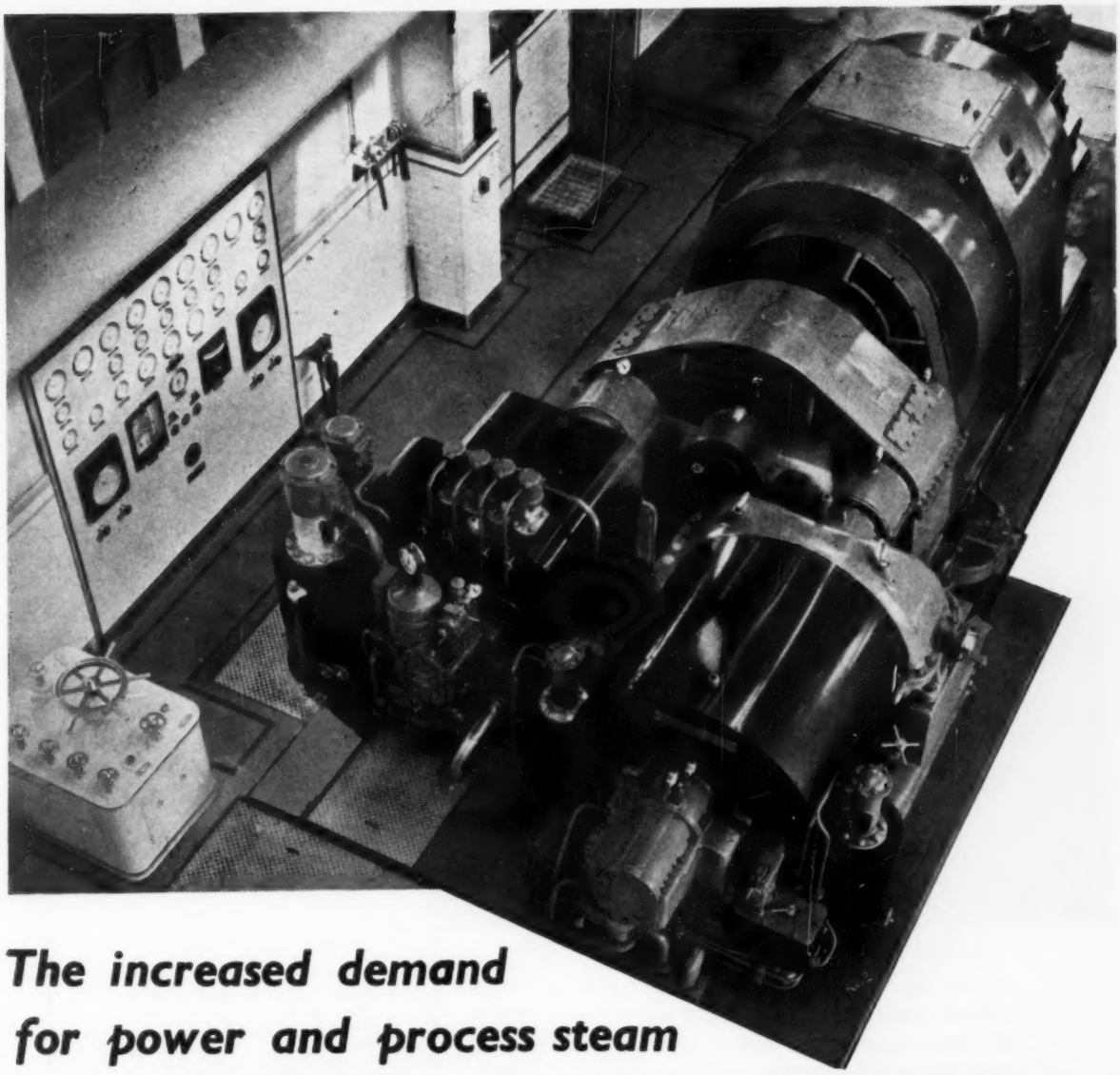
Yorkshire Imperial service includes research, investigation, and other work prior to installation, to determine the correct tube or plate alloy, or fitting, to meet the requirements of the industry's diverse plant and equipment, and ensure its smooth and trouble-free operation.

The **Yorkshire Imperial** laboratories are equipped with the most modern apparatus for research, metallurgical control and examination of non-ferrous products. There are also facilities for the analysis and examination of cooling water supplies, and for making comparative accelerated corrosion tests on a variety of non-ferrous alloys.



Head Office: P.O. Box 166, Leeds Telephone: Leeds 7-2222

~~1000kW~~ 4000kW in the same space



The increased demand for power and process steam

at BOOTS THE CHEMISTS *factories is met by this 4000 kW turbo-alternator*

• • •

ALLEN TURBINE POWER PLANT

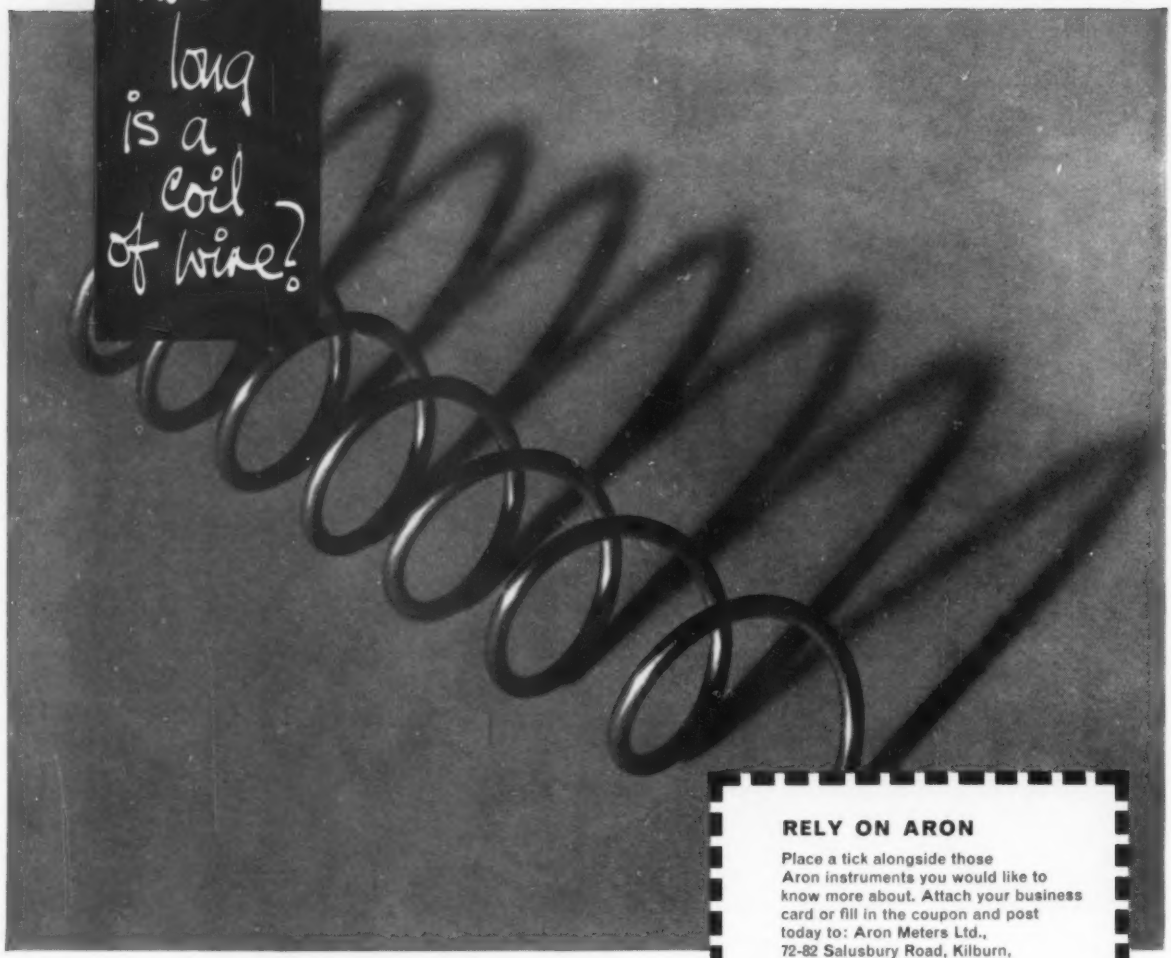
Process steam is used extensively in the production of many products at the large factories of Boots Pure Drug Co., Ltd., Beeston, near Nottingham, for which the total steam requirements and the complete electricity needs are provided by turbine plant of 11,750 kW capacity.

This latest turbo-alternator is an example of the compactness achieved with modern design. The set occupies the same site as an earlier 1,000 kW machine, yet generates four times the power output. It comprises an Allen twin-cylinder, cross-compound pass-out condensing turbine with the high- and low-pressure cylinders side by side, driving a B.T.H. alternator through Allen two-pinion speed-reduction gearing. The turbine is designed to take steam from the works' boiler plant at 340 p.s.i.g. and 650 F., and to pass out up to 96,000 lb. of process steam per hour at 60 p.s.i.g. Although the set has a continuous maximum rating of 4,000 kW, it is also capable of generating 3,000 kW, either with no pass out or with the maximum pass-out quantity, thus providing flexibility to meet the works' electrical load despite appreciable changes in the process steam demand.

An installation of this kind may well provide the answer wherever a works' power and process steam requirements grow beyond the capacity of existing plant.

W. H. ALLEN SONS & Co LTD BEDFORD ENGLAND

Telephone: Bedford 67400. *Telegrams:* Pump Bedford Telex *(Telex No. 82100)*



How far has it stretched since 1883? How can it measure the achievement of an industry? In 1883 Professor Aron invented the electricity meter. Since then, many thousand miles of wire have carried current through Aron measuring devices, and electronics has joined electromagnetics in the Aron industrial programme. Our summation equipment, wear-free because it is electronic, fault-free because it is Aron, is used in factories, hotels, office blocks to measure and record electrical energy used. As with every Aron instrument, it is taking Aron experience, service and economy to countless users throughout the world. Today's demand for Aron meters is greater than at any time in our successful pioneering history. It is an achievement of which we are justly proud.

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Cranes for Power Houses

Among Arrol's latest contributions to Britain's power supply resources is the 135 ton electrical overhead travelling crane pictured, and two of 75 and 25 tons capacity respectively. These are operating at Hams Hall 'C' Power Station and they are serving your interests with the exceptional efficiency characteristic of all Arrol crane designs.

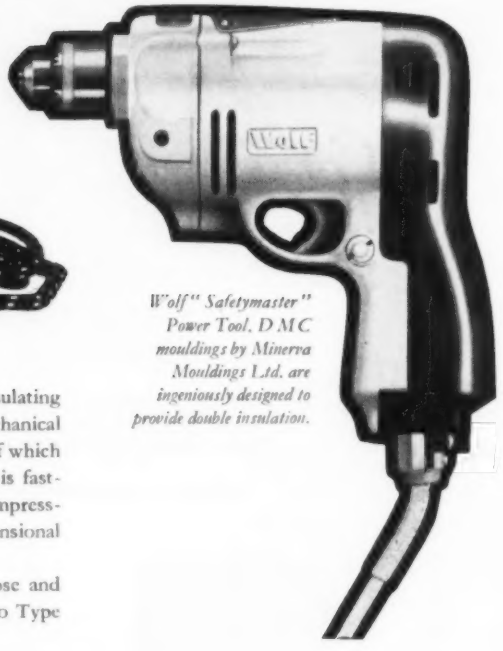
All types of Steel Framed Buildings; Fixed and Opening Bridges; Cranes and Mechanical Engineering Work; Dock Gates; Sliding and Floating Caissons; Compressed Air Locks; Hydraulic Machinery; Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Projects.

SIR WILLIAM ARROL & CO LTD GLASGOW Arrol

Siemens-Ediswan 60-amp Input Junction Box moulded in D M C in four parts by AEI. (Aldridge) Ltd.

BEETLE* for DMC DURABILITY

Good-looking grille on Morphy-Richards Fan Heater is a moulding by Crystalate (Mouldings) Ltd. in a special "thin flash" grade (L.1834) of Beetle D M C.



Wolf" Safetymaster" Power Tool. D M C mouldings by Minerva Mouldings Ltd. are ingeniously designed to provide double insulation.

Beetle Polyester D M C is equally outstanding for its electrical insulating and anti-track properties as for its high heat resistance and mechanical strength. That's why it is unbeatable for high-duty applications, of which the examples shown are typical. D M C is economical because it is fast-curing and simple to mould under low pressure in conventional compression and transfer presses. Compatibility with metals and dimensional stability are above normal for thermosetting materials.

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for

DRAKELOW 'C' POWER STATION

DRAKELOW 'C' will be the first Central Electricity Generating Board power station to be equipped with boiler plant operating at supercritical pressure.

The boiler to be supplied by

BABCOCK & WILCOX LTD.

will comprise a 'once-through' unit, pulverized-fuel fired, with an evaporation of

2,500,000 lb./hr.,

with steam conditions of

3,650 lb./sq.in. (s.o.p.)

1,110°F

AND REHEAT TO 1,055°F, 713 lb./sq. in.

to steam a

375 M W GENERATOR

This Company, which is able to draw upon a considerable experience of supercritical-pressure boiler plant in other Babcock installations, is proud to be in the forefront of this important advance, with its potentiality for valuable increases in power station overall thermal efficiencies.

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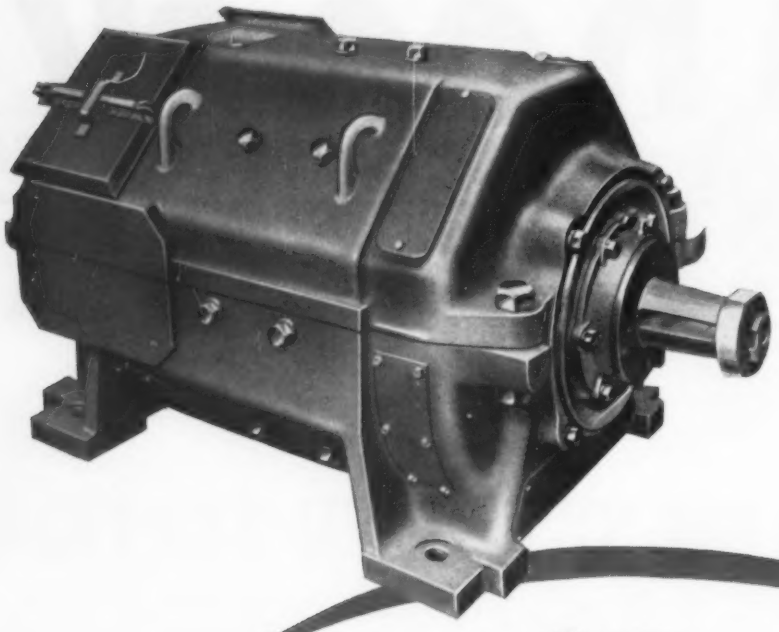

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Over 4,000 MDX-type mill motors have gone into service during the last eight years in leading iron- and steel-producing works in Britain and many other parts of the world. They have established a good reputation for efficient and continuous duty. Remarkable reliability and strength, together with low inertia of rotating parts, make MDX motors ideal for driving a wide range of steelworks equipment. They have been specifically designed to withstand arduous service and are unaffected by heavy overloads. Available totally enclosed, up to 200 h.p., self-ventilated, up to 250 h.p.

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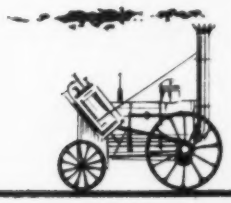

STEAM

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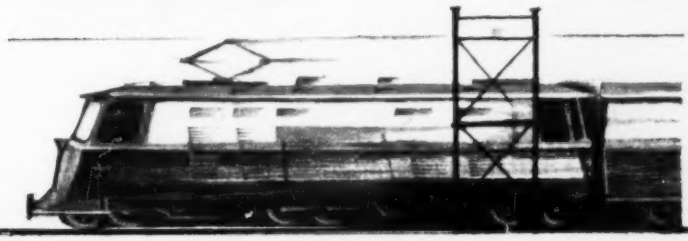

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High Conductivity Copper products are used extensively by the manufacturers of electric and diesel-electric locomotives for use in field coils and armature coils, for commutator bars of traction motors, generators and auxiliary machines, and also for components of control equipment and for pantograph wearing strips.

BRITISH TRANSPORT COMMISSION
25kV.50-cycle Electrification Scheme

Bolton's H.C. Copper is used in the commutators of the motors of a.c. electric locomotives, and in the control gear, and in traction motors of a.c. multiple-unit trains.

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CVS-569

It's aluminium

Sheathed in *seamless* extruded aluminium, this cable is lightweight yet strong. It needs no armouring, thus allowing simple cable design. With a high resistance to vibration fatigue, it can be uased with complete safety, alongside railways etc.

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Corrugation results in greater flexibility, permitting the same bending radius as a lead sheathed cable. Not only are handling qualities improved but corrugation reduces the required thickness of the sheath *by one half*.

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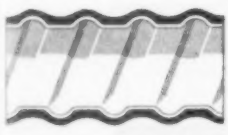
Initial costs are therefore lower than conventional type cables of similar performance. Lightness and flexibility simplify transportation and installation. No special precautions are necessary to allow for expansion and contraction.

Further information is available on request.

It's the BICC C.S.A. cable

CORRUGATED
SEAMLESS
ALUMINIUM



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Anti-corrosion protection is provided by an extruded P.V.C. covering which fits tightly over the whole sheath surface. *See section view.*

INSTALLATION

Conventional installation procedure is followed. Jointing techniques are the same as for normal smooth aluminium-sheathed cables.

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C.S.A. sheathing is available with BICC Mass - Impregnated Non - Draining (M.I.N.D.) Cables up to 33kV and for Oil-Filled Cables.

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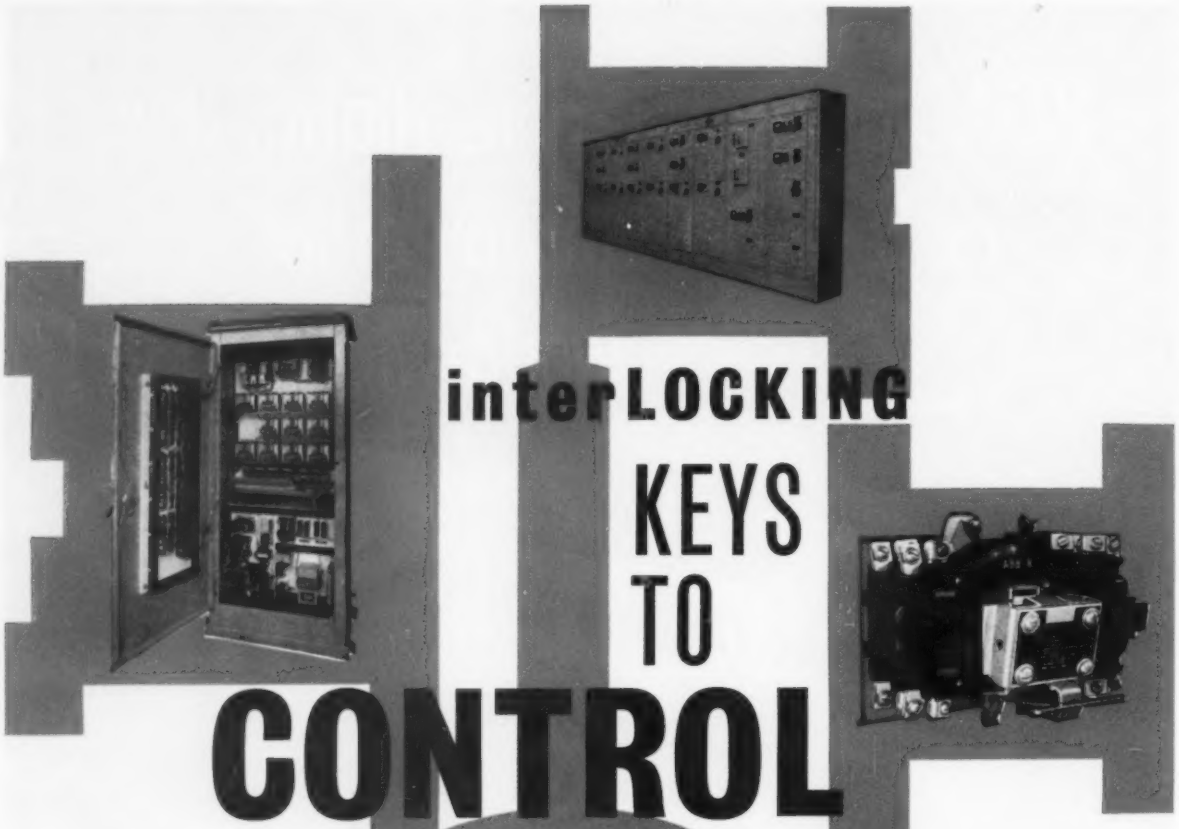

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Brookhirst Igranic offer a diversity of electrical control systems. To many of the problems that are brought to us we can offer a choice or a combination of several solutions—contactor/relay switching; BI-Stat contactless switching (either of them with or without direct feedback); closed loop systems using rotating or static magnetic amplifiers, or semiconductors, or both; and so on.

Brookhirst Igranic's wide experience enables our design engineers to specify exactly the systems to suit your needs.

It is at an early stage in your project that we can be most helpful. Your plant, and its control circuitry & equipment, will then be designed together.

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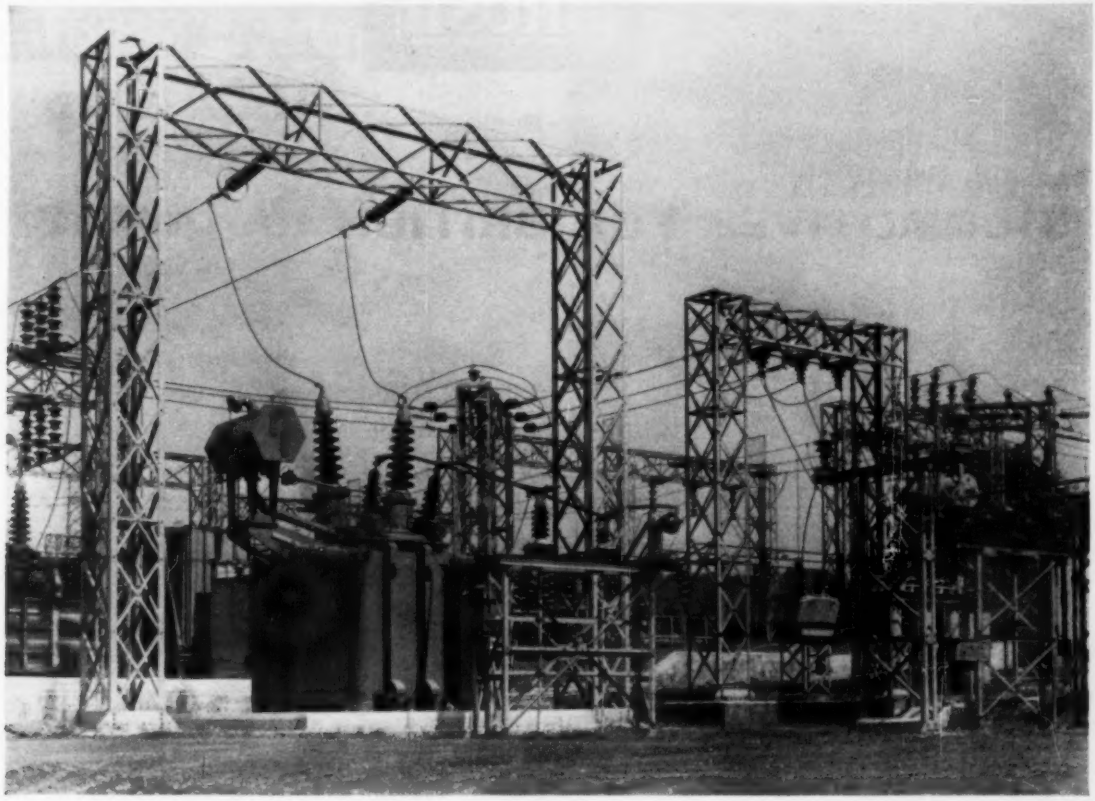

TRANSFORMERS FOR RAILWAY ELECTRIFICATION

136 MVA of transformers in sizes from 3 MVA to 10 MVA have been supplied for British Railways Eastern Region and Glasgow suburban (Stage 1) electrification schemes for the supply of power to the overhead conductor systems at 25 kV and 6.25 kV.

The illustration shows Strathleven substation of the North of Scotland Hydro-Electric Board with 5 MVA single-phase 132/25 kV transformers for supplying power to British Railways electrified lines in the Glasgow suburban district.

Bruce Peebles & Co. Limited, Edinburgh, manufacture heavy rotating plant for the generation and conversion of electrical energy; power transformers for the highest voltages, transformers and rectifiers for railway traction and other services, automatic control and electronic equipment; electric motors for industry.

BRUCE PEEBLES & CO. LIMITED, EDINBURGH

BRUSH

TWO HUNDRED
AND TWENTY SIX
LOCOMOTIVES FOR BRITISH RAILWAYS

226 Brush Type-2, 1250-1365-1600 H.P. Diesel Electric Locomotives have been ordered for British Railways, over half of these are already in service and output is maintained at a steady two locomotives per week.

BRUSH TRACTION DIVISION

BRUSH ELECTRICAL ENGINEERING CO. LTD. LOUGHBOROUGH, ENGLAND *(A Member of the Hawker Siddeley Group).*

THE NEW TUDOR 'SAFETYLYTE' EMERGENCY LIGHTING EQUIPMENT

There is now an advanced version of the well-established Tudor 'Safetylyte' Emergency Lighting Equipment – the equipment that springs automatically into action the moment any interruption occurs in the normal mains supply, and provides emergency lighting protection in any type of public building.

This advanced equipment makes full use of the new Tudor High Performance Cell, and is housed in a cubicle of improved design. The larger cubicles are now constructed of folded sheet steel with the instrument panel recessed and the front door hinged to give ready access to internal components.

The equipment is available in both maintained and non-maintained types. For small lighting loads, wall-mounted cubicles (employing automatic mercury relay in place of a contactor) can be supplied. Self-contained trickle charge/floating battery equipment has also been designed for small buildings.

Tudor SAFETYLYTE

EMERGENCY LIGHTING EQUIPMENT

THE D.P. BATTERY COMPANY LIMITED
MANUFACTURERS OF KATHANODE AND TUDOR BATTERIES
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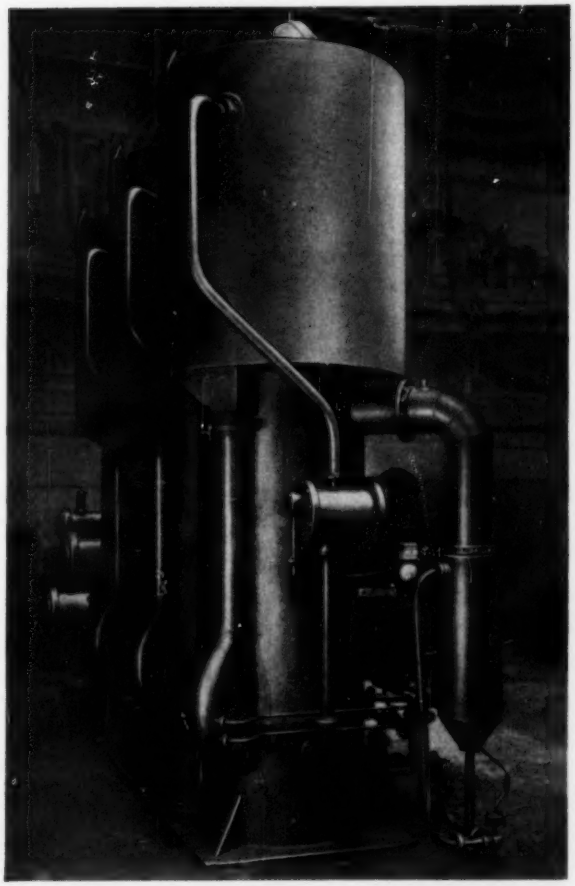


Triple effect re-compression type evaporator for 25,000 lb/hr. feed water

Evaporating Plant

The trend towards higher boiler pressures and temperatures creates a need for greater purity of the feed water. Whilst the bled steam unit evaporator, incorporated in the feed system, is economically the best source of pure water for sets with a fairly steady load factor, independent central evaporating plant (incorporating vapour re-compression for economy) has many advantages, particularly for intermittent operation.

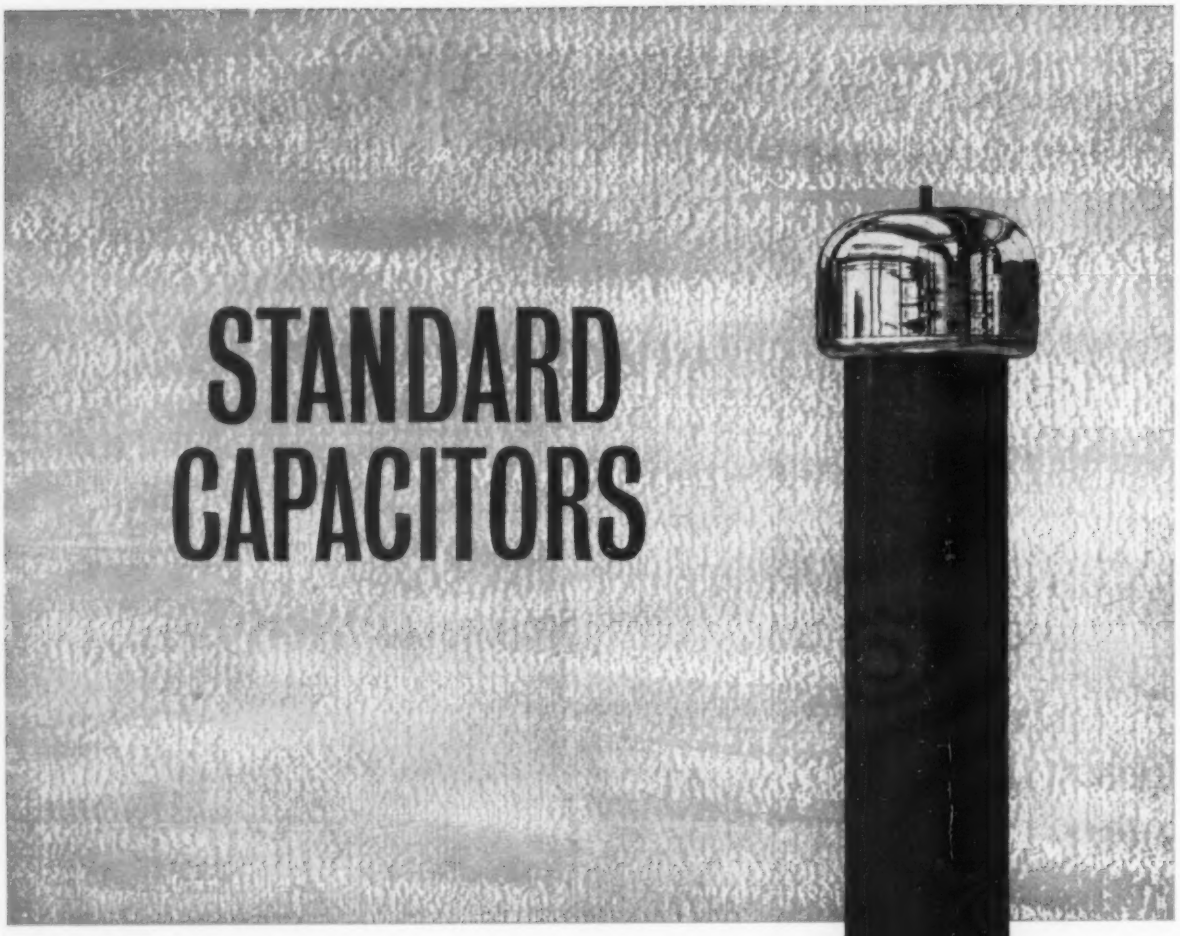
Hick Hargreaves supply bled steam unit evaporators, also vapour re-compression central plants in single, double, or triple effect of capacities up to 40,000 lb/hour (18,000 kgs/hour).

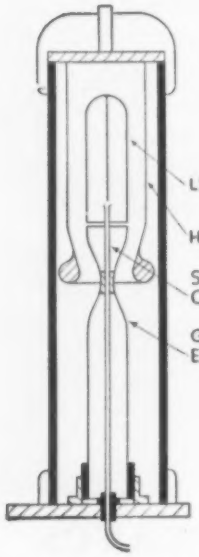
Hick Hargreaves

AND COMPANY LTD · BOLTON

H 152

STANDARD CAPACITORS

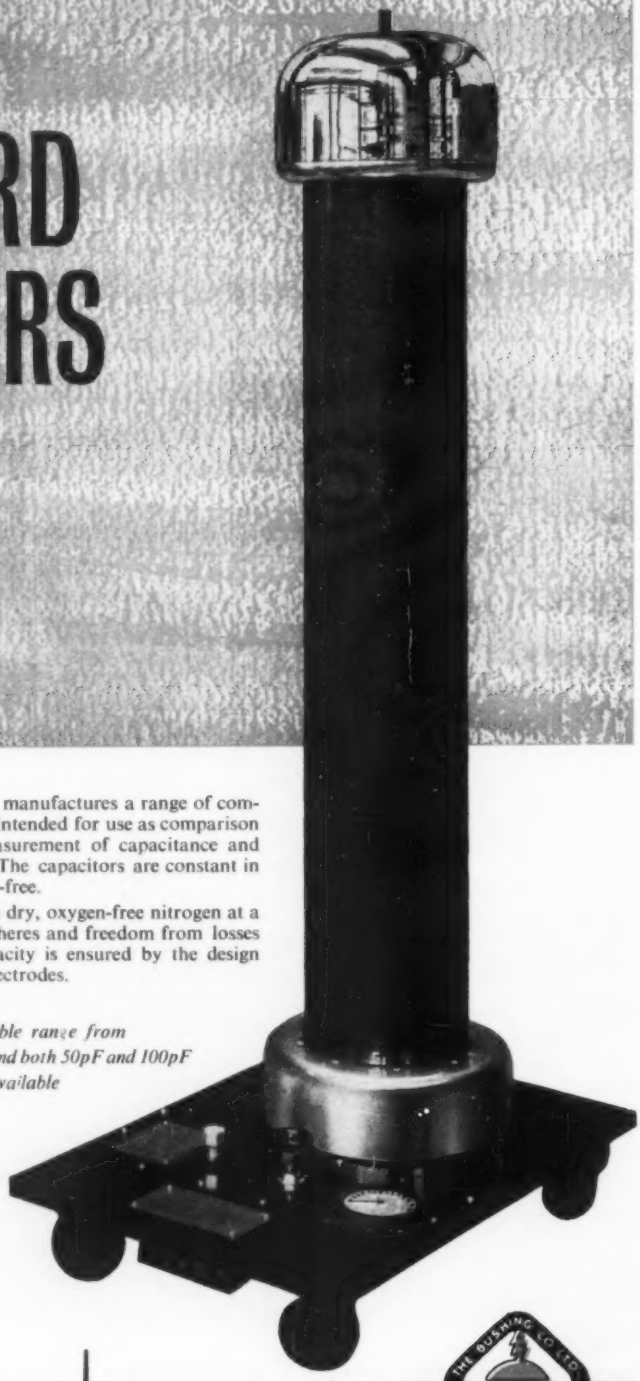




The Bushing Co. Ltd. manufactures a range of compressed gas capacitors intended for use as comparison standards for the measurement of capacitance and dielectric loss factor. The capacitors are constant in value and virtually loss-free.

The gaseous insulant is dry, oxygen-free nitrogen at a pressure of 10 atmospheres and freedom from losses and invariance of capacity is ensured by the design and screening of the electrodes.

The sizes available range from 50k V to 500k V and both 50pF and 100pF capacitors are available in each size.



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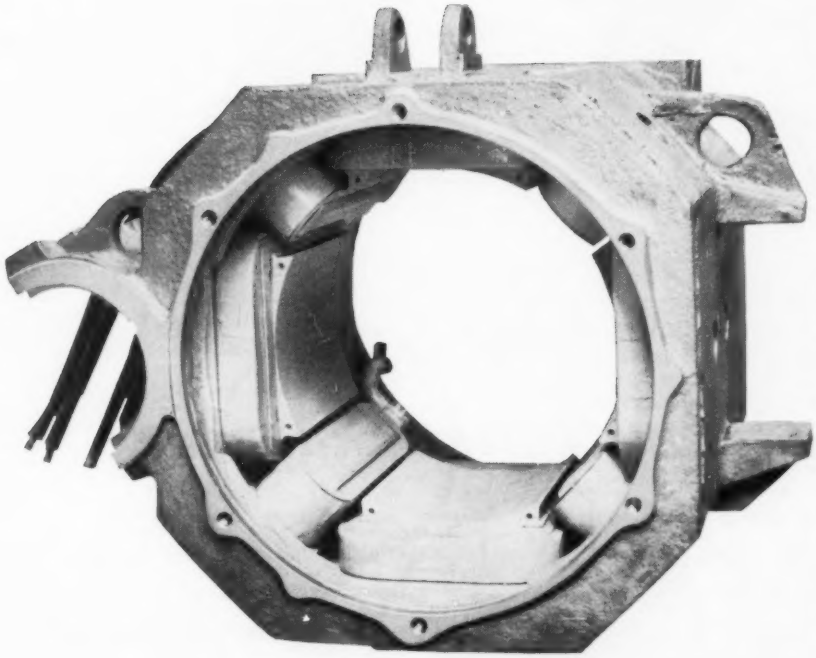
B5

DESIGNING

AND MAKING TRACTION EQUIPMENT



Engineers today have entered upon an era of re-thinking. Something that has always been known, but which has been neglected in the more recent phase of the purely mathematical approach, is now being rediscovered. It is that engineering design is an art as well as a science. This is really no news to the good designer who goes on quietly trusting his eye and his feeling for a sound job. But where does his knowledge—his flair—come from? Quite largely, it seems, from experience. Some of it his own, much of it the common stock of the people he works with. It is the channel through which the total experience of an engineering company such as our own is fed back into new products.

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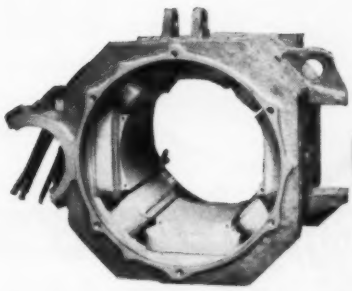

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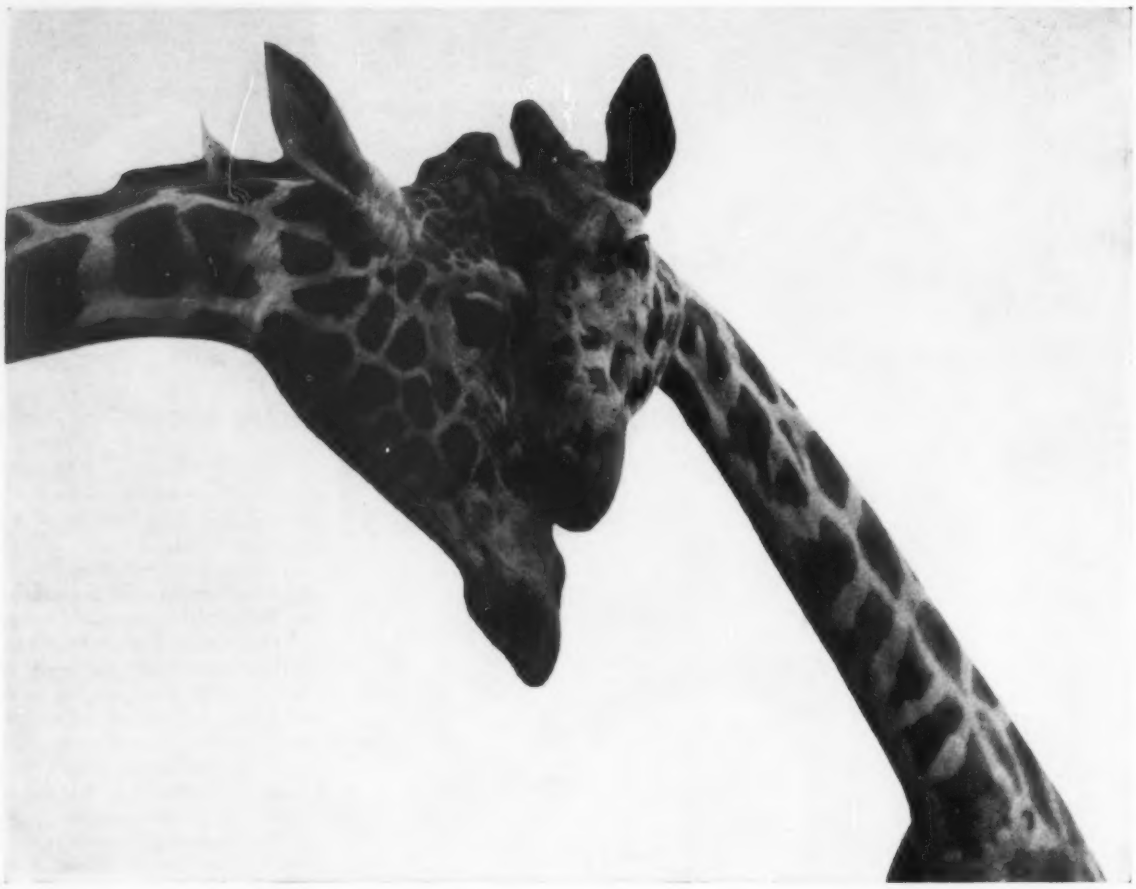

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Education Committee

HENDON TECHNICAL COLLEGE

The Burroughs, Hendon, N.W.4

Applications are invited for the following posts. Duties to commence as soon as possible and in any case not later than 1st January, 1961.

Electrical Engineering Department

TWO SENIOR LECTURERS to teach one or more of the following to the level of the Part III examination of the Institution of Electrical Engineers:

Advanced Level Engineering
Electrical Measurements
Electrical Supply

Candidates should be graduates and corporate members of the Institution of Electrical Engineers.

ASSISTANT GRADE B to teach Electrical Engineering subjects (heavy current) up to Higher National Certificate Standard. Candidates should be graduates or corporate members of the Institution of Electrical Engineers.

Mechanical Engineering Department

PRINCIPAL LECTURER to teach one or more Mechanical Engineering subjects to post Higher National Diploma Standard. Candidates should be honours graduates and corporate members of the Institution of Mechanical Engineers.

SENIOR LECTURER to teach Theory of Machines to Higher National Diploma Standard. Candidates should be graduates and corporate members of the Institution of Mechanical Engineers.

LECTURER to teach one or more Mechanical Engineering subjects to Higher National Certificate Standard.

ASSISTANT GRADE B to teach one or more Mechanical Engineering subjects to Ordinary National Certificate Standard. Candidates for these two posts should be graduates and/or corporate members of the Institution of Mechanical Engineers. Salary within the range (men):

Principal Lecturer	£1,788—£1,951 per annum
Senior Lecturer	£1,588—£1,801 per annum
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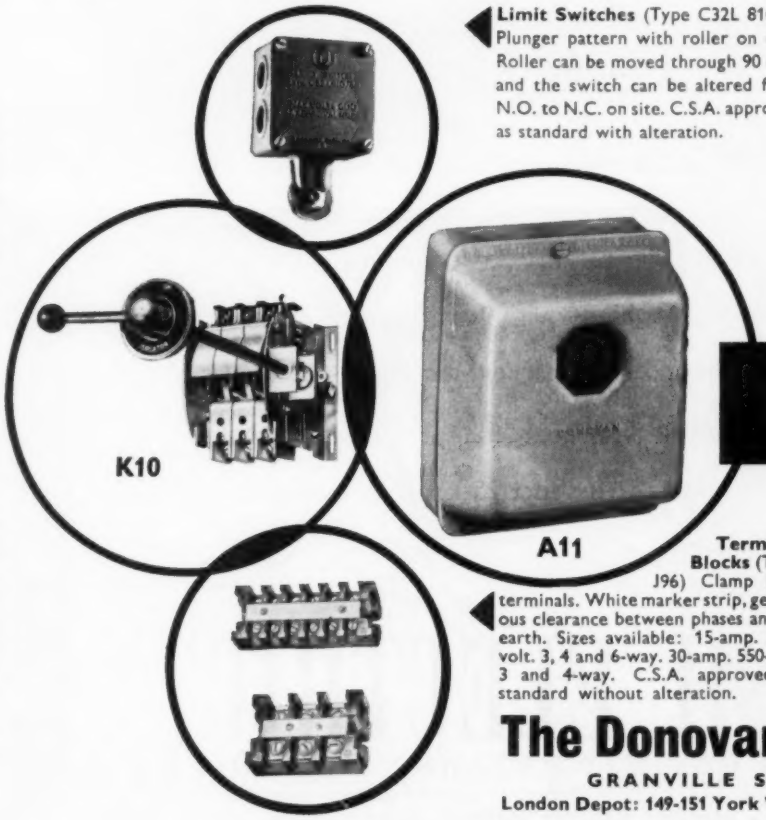
Assistant Grade B (graduate)	£828—£1,486 per annum

Application forms and further details (s.a.e.) from the Clerk to the Governing Body, Town Hall, Hendon, N.W.4, to whom completed forms must be returned within two weeks from the date of appearance of this advertisement.

C. E. GURR, M.Sc., Ph.D.,
Secretary to the Education Committee

A SELECTION FROM A LARGE RANGE



Limit Switches (Type C32L 810/1) Plunger pattern with roller on end. Roller can be moved through 90 deg. and the switch can be altered from N.O. to N.C. on site. C.S.A. approved as standard with alteration.

K10. Load Breaking Isolating Switch with Visible Blade Isolation and front operation. 45-amp. 550-volt. For building into Contactor gear control panels.

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Terminal Blocks (Type J96) Clamp type terminals. White marker strip, generous clearance between phases and to earth. Sizes available: 15-amp. 550-volt. 3, 4 and 6-way. 30-amp. 550-volt 3 and 4-way. C.S.A. approved as standard without alteration.

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Modernisation in practice

Fifteen of these 3,000 h.p. 25 kV 50 cycle locomotives are being supplied to British Railways. Weighing 73 tons in working order, the locomotives are for use on the recently opened Manchester-Crewe electrified lines of the London Midland Region.

"ENGLISH ELECTRIC" equipped the first 25 kV A.C. multiple unit stock to operate in Great Britain.

'ENGLISH ELECTRIC'

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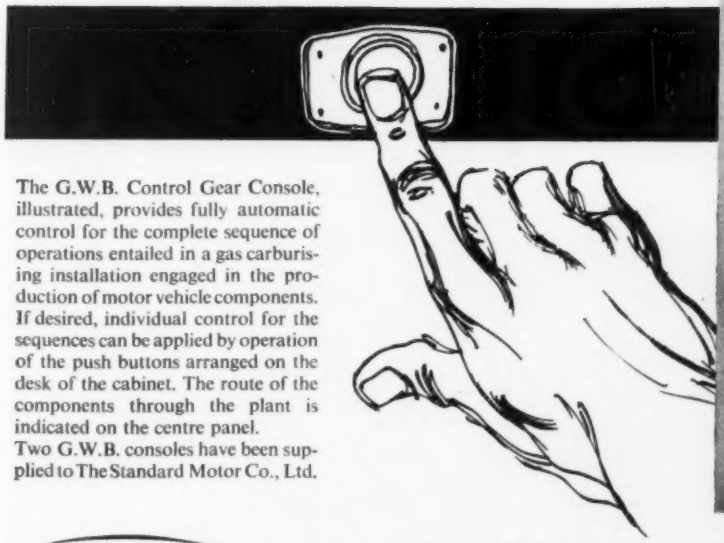
STANDARD TRIUMPH

USE G.W.B. CONTROL GEAR



The G.W.B. Control Gear Console, illustrated, provides fully automatic control for the complete sequence of operations entailed in a gas carburising installation engaged in the production of motor vehicle components. If desired, individual control for the sequences can be applied by operation of the push buttons arranged on the desk of the cabinet. The route of the components through the plant is indicated on the centre panel.
Two G.W.B. consoles have been supplied to The Standard Motor Co., Ltd.

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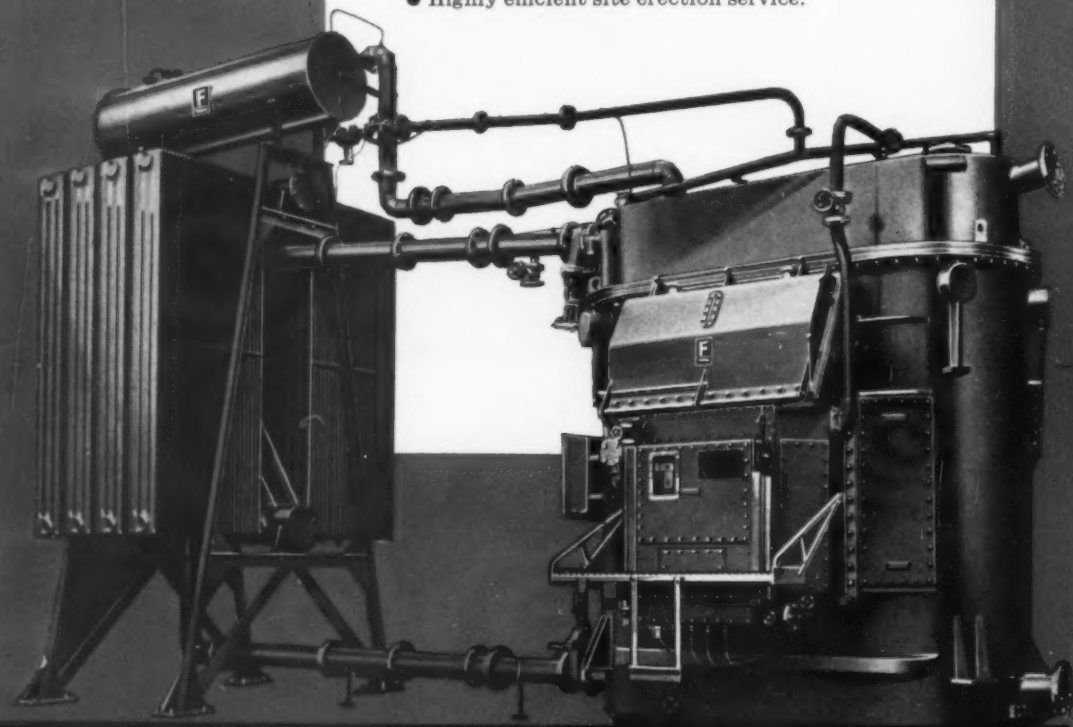

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* Higher breaking capacity. Improved arc shielding gives increased performance on breaking capacity tests.
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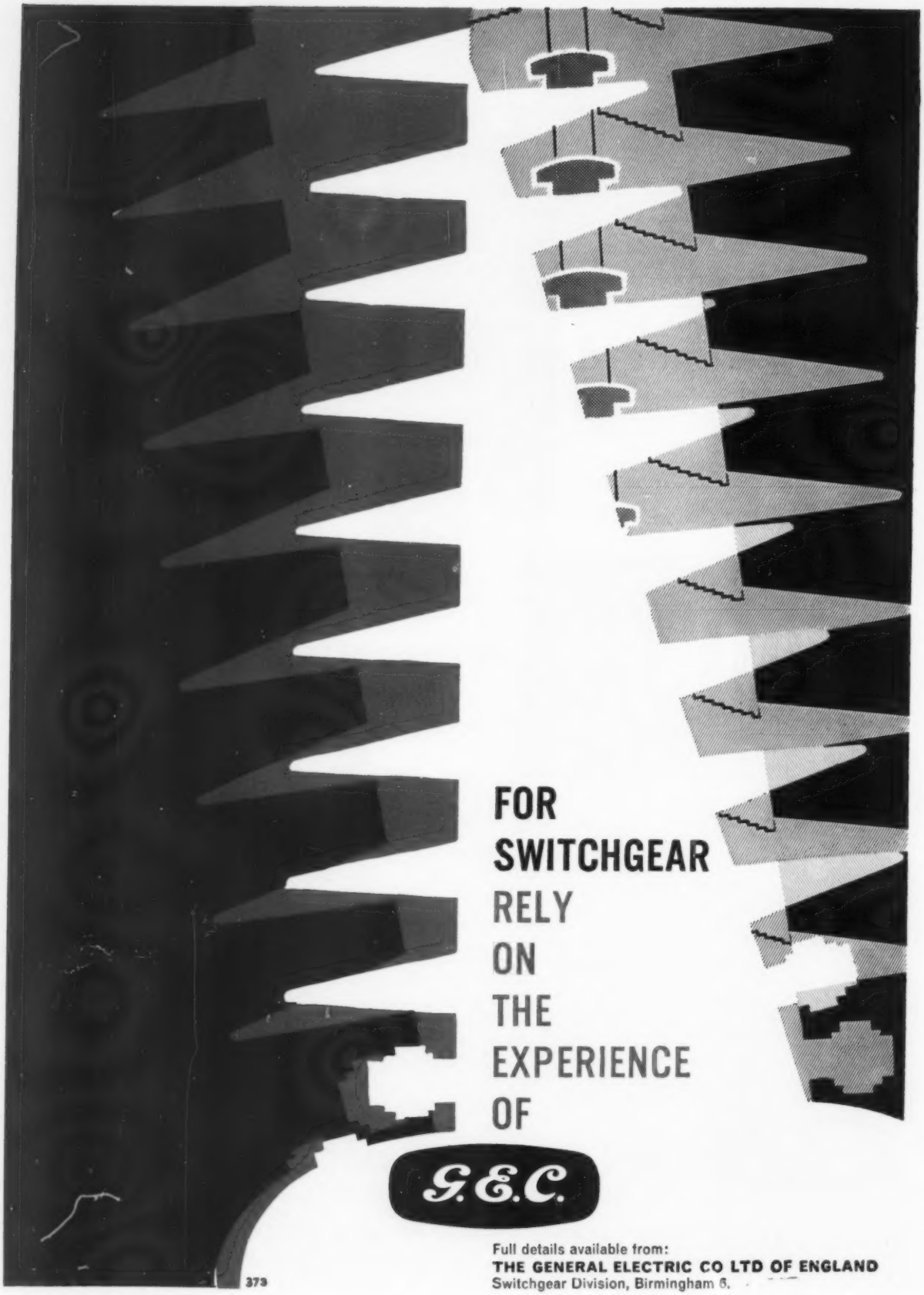

Full details available from:
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A NEW EMI HIGH TORQUE BATTERY MOTOR

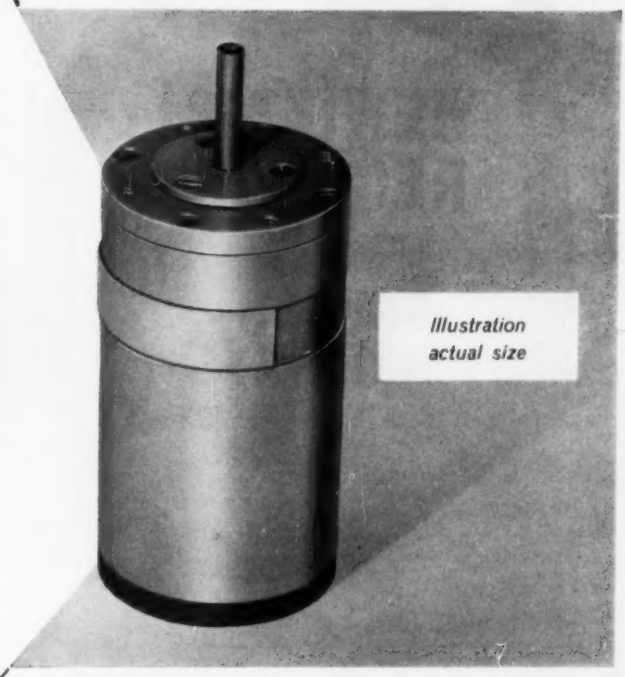


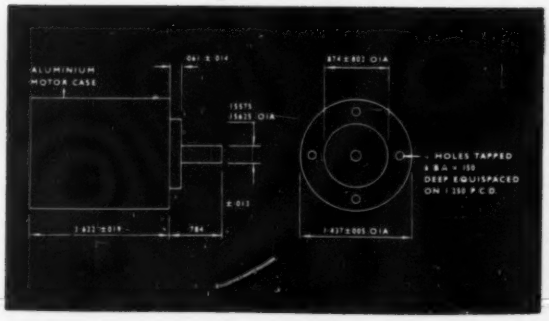
Illustration actual size

For Professional and Scientific Applications

Designed primarily for Professional Tape Recorders this new EMI Battery Motor (part no. 98170D) is also suitable for Television camera remote control, and for medical and other scientific uses. A high-grade precision-built Motor for long life and exceptional speed regulation over a wide range of load and voltage. A Multi-pole Armature gives low electrical interference, long brush life and high efficiency and a Ball Race bearing is incorporated for handling heavy duty side loads.

Provisional Technical Specification

Voltage Range:	8v to 12v DC
Current:	No load 120mA max. 8-12v At 45 gcms 310mA max. 8-12v
Rotation:	Anticlockwise viewed from spindle end.
Speed and Output:	Max. continuous rating. 2440-2500 r.p.m. at 45 grm. cms. torque at 12v DC +0v 2390 r.p.m. minimum at 45 grm. cms. torque at 8v DC −0v Speed regulation over governed range at constant voltage 0.75 r.p.m. per grm. cm. torque. Speed regulation over governed range at constant torque 12·5 r.p.m. per volt DC Max. No load ungoverned 12v No load governed 8v Minimum torque at governed speed 15 grm. cm. at 12v DC.



EMI also manufacture a wide range of inexpensive battery motors suitable for Domestic Tape Recorders, Gramophones, Fans and a host of other applications where a governed torque of up to 10 gm. cm. at 1600 r.p.m. or 2600 r.p.m. is required.

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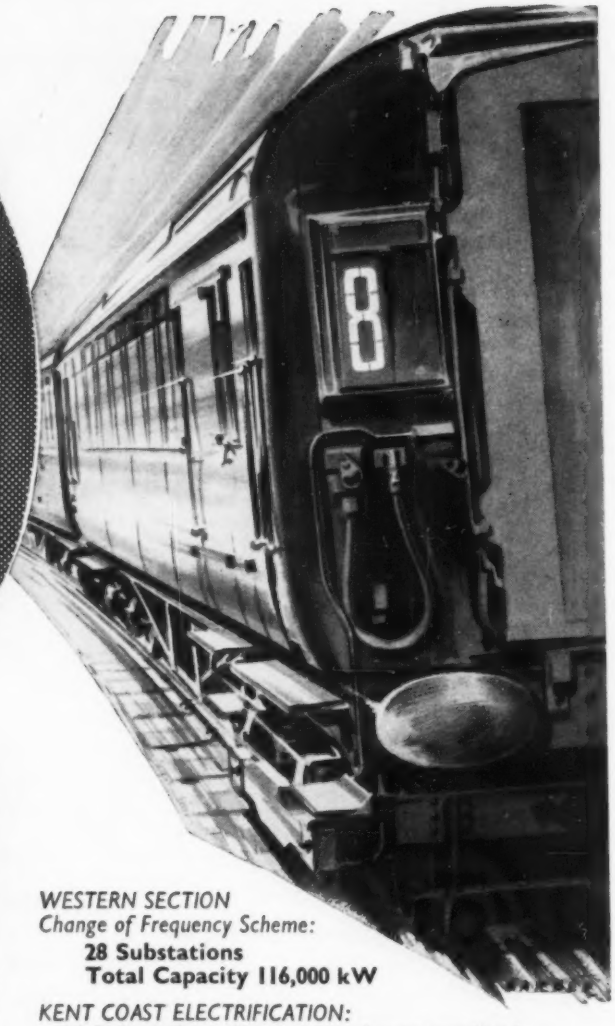

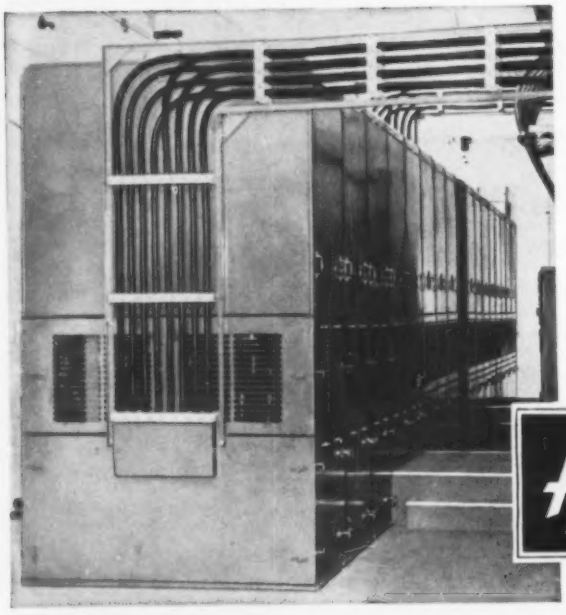

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28 Substations
Total Capacity 116,000 kW

KENT COAST ELECTRIFICATION:
31 Substations (in course of construction)
Total Capacity 82,500 kW

The illustration left, shows two Hewittic Rectifiers forming a 5,000 kW bank in the Dover Substation.

Hewittic Rectifiers

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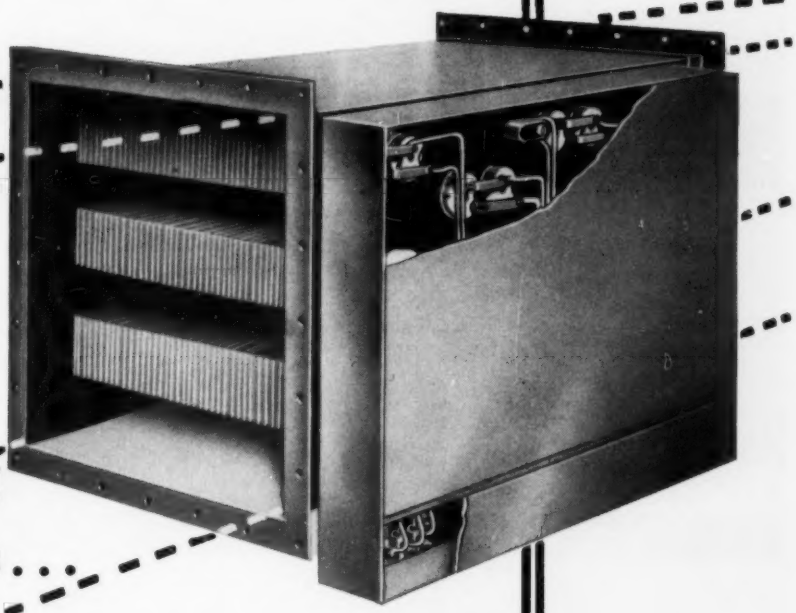
for fitting into ducting of air conditioning Plenum systems . . .



. . the specialised experience of **Heatrae**

Heatrae Duct Type Air Heaters are made in a wide range of sizes, the usual cross sections being 14", 18" and 33" square, and 18" x 33". Special sizes can be made to suit existing ducting where required. These heaters are constructed from steel, for use with a static head of a few inches water gauge only, but special types are offered for higher pressures and temperatures. Normal temperature control is by thermostat with master thermostat and hand reset button provided.

Maximum working temperature of standard heaters . . 400°F.

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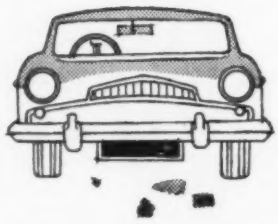
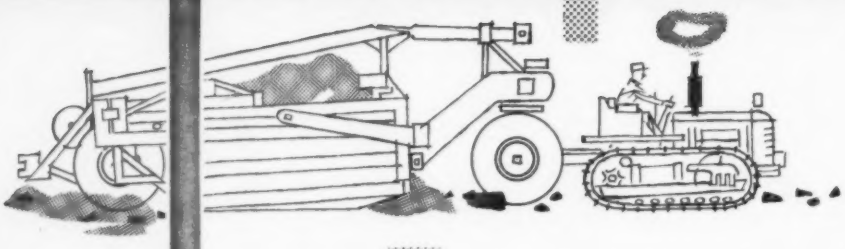
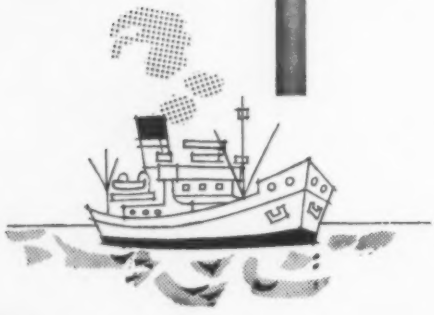


service to industry





'GENWAY' ELECTRODES

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'SPEEDWAY' ELECTRODES

Most economical due to fast running at comparatively low currents with very good penetration. Excellent for general engineering work, simple operation and easy slag removal.

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NORWEGIAN.

Det Norske Veritas — All positions. Also for welding "W" and "WW" quality steels.

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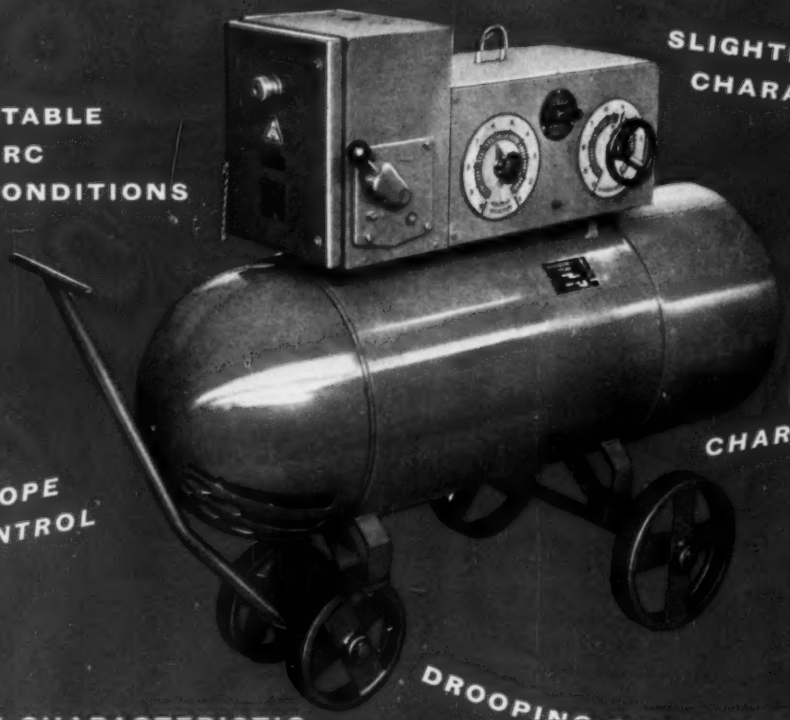

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A new and important advance
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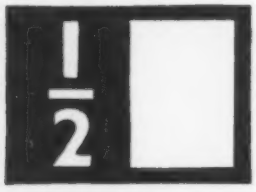
Stand-by power in



the space

FROM THE **NEW**

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This new cell is specially designed for standby duties entailing discharge rates between, say, the 3-hour and the very high rates demanded for switch-closing purposes. With its Planté positive and pasted negative plates, Porvic microporous separators and many other improvements in material and in design, this light, robust cell will perform its duties with greater efficiency, with complete reliability and with a saving in battery space of approximately 50%. It is ideal for trickle-charge operation* and has all the remarkable length of life of the Planté type of construction. In Great Britain today standby batteries occupy millions of cubic feet of valuable space. The new Chloride cell could free almost half of it.

** The new cell will from now onwards be fitted in all Keepalite units—the Chloride Company's automatic emergency lighting system.*

By the makers of Exide Batteries

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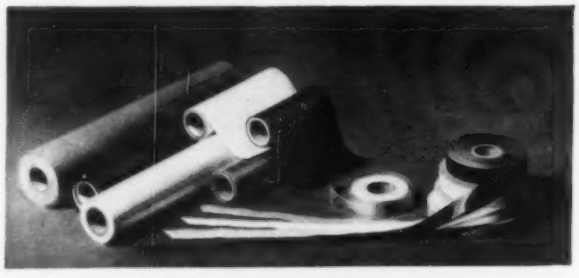

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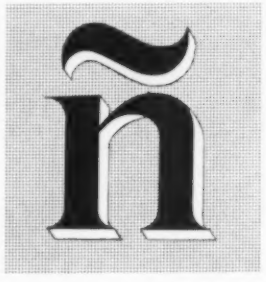

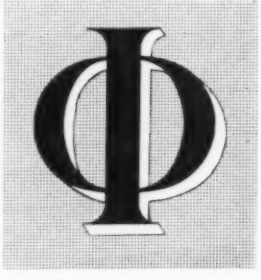

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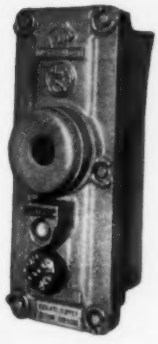

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MK have introduced a new range of boxes and clamps for MICC cable. Single or double entry clamps are interchangeable with any of the boxes and are supplied separately with fixing screws and shakeproof washers. Steel boxes and cable clamps are zinc plated.

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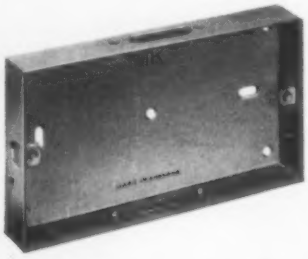
PLASTER-DEPTH BOXES FOR M.I.C.C. CABLE

These boxes have one clear entry and one knockout for attaching either single or double entry cable clamps.

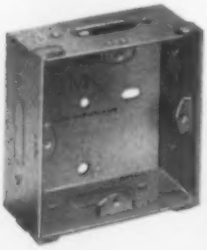
List No. 3951 — Plaster-depth box with 2⅜″ fixing centres.



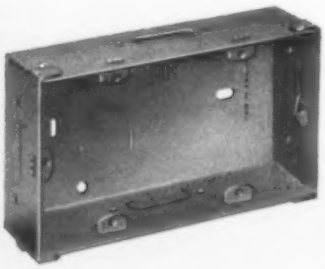
List No. 3952 — Plaster-depth box with 4¾″ fixing centres.

DEEP BOXES FOR M.I.C.C. CABLE

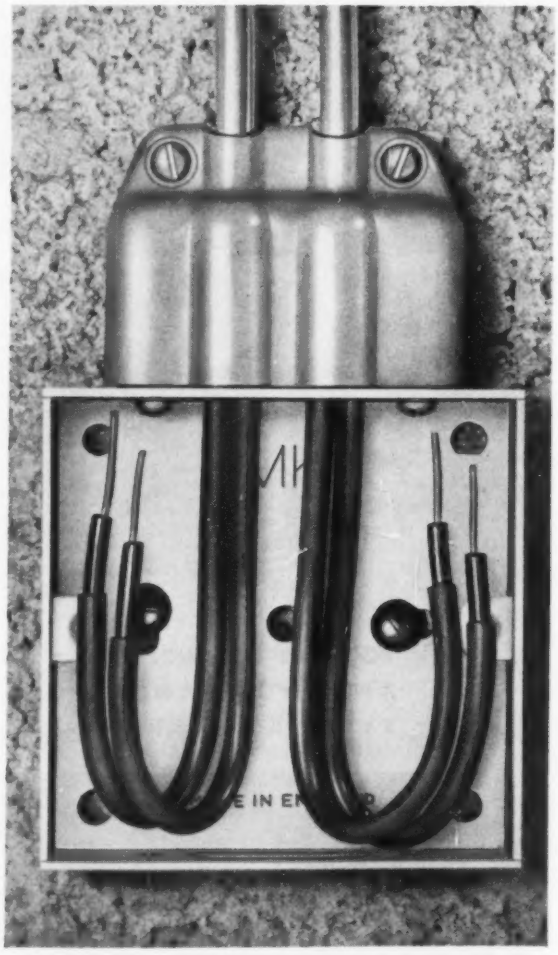
Deep boxes have one clear entry on one side and one knockout on each of the other three sides and one in the back to which can be attached a single or double entry cable clamp.



List No. 881 — Box to BS 1299/1363 dimensions having 2⅜″ fixing centres.



List No. 882 — Box to accommodate any two gang MK accessory.



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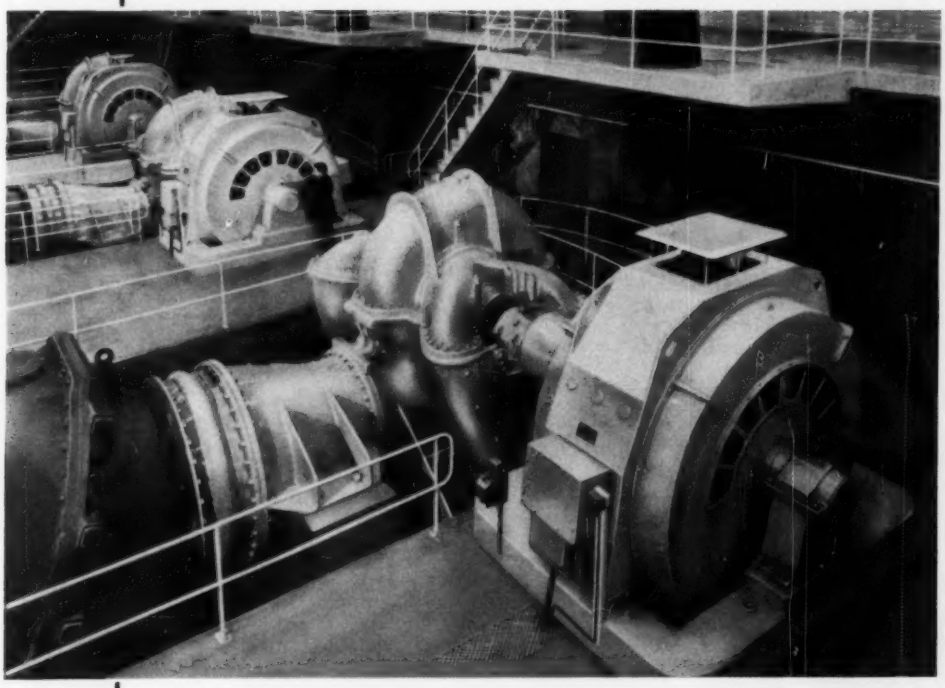

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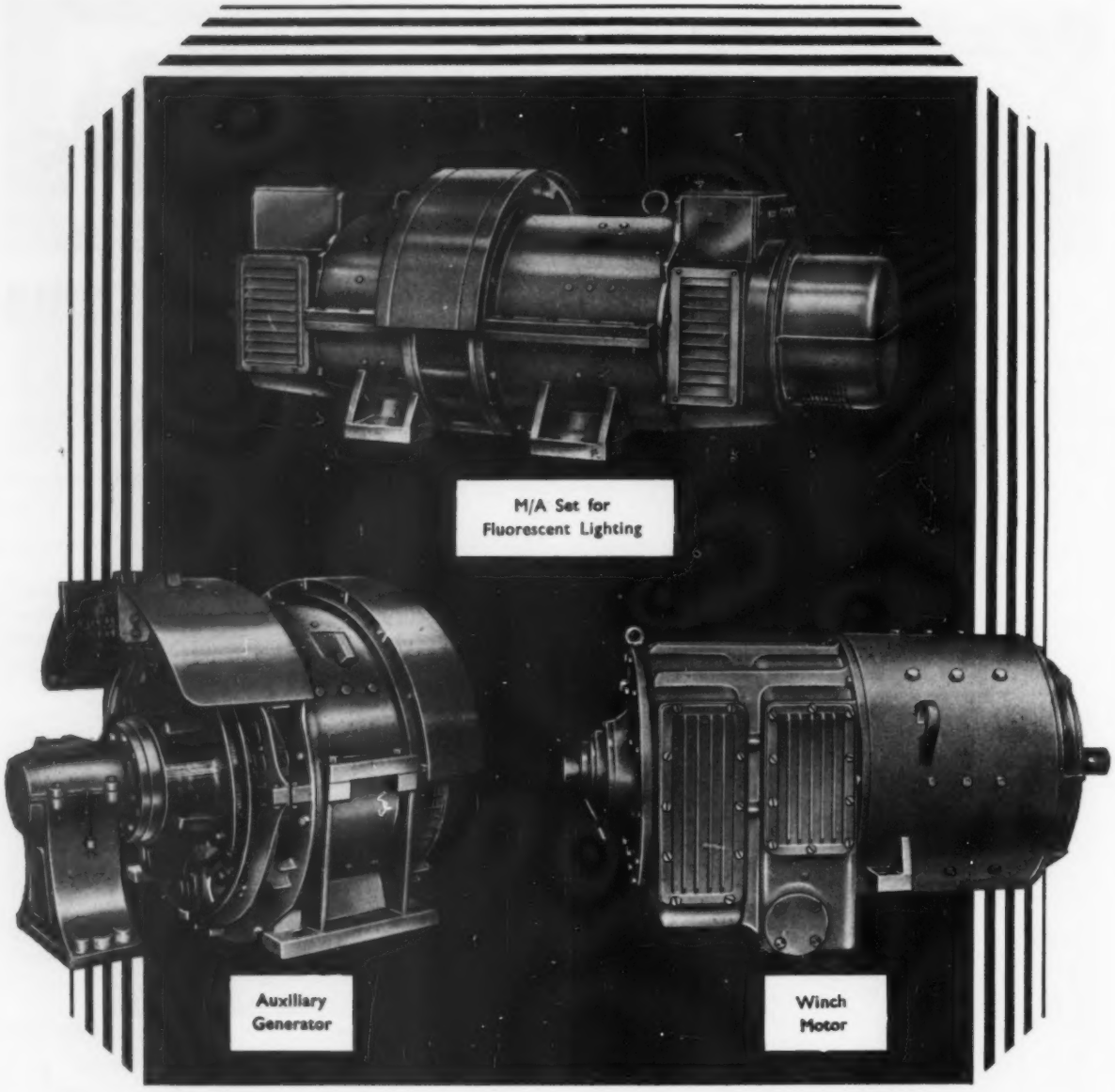

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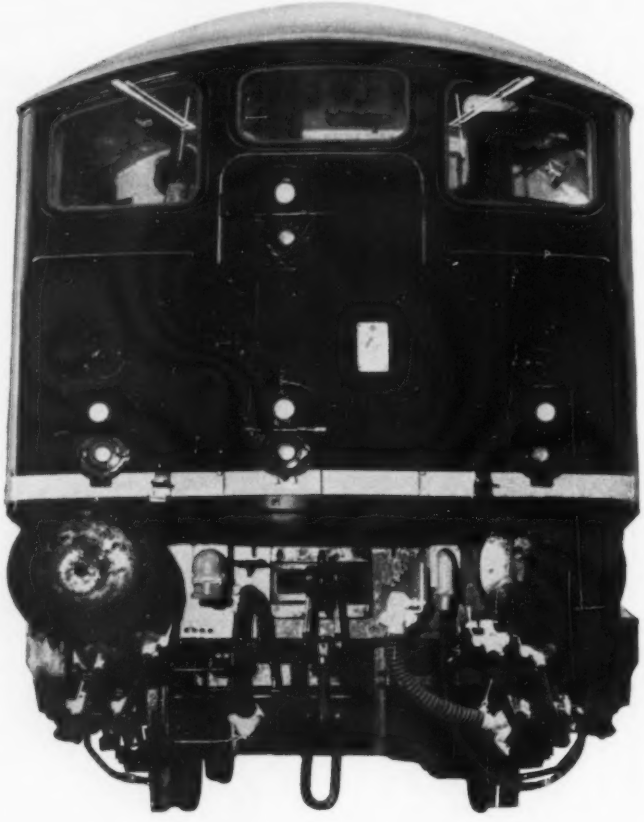

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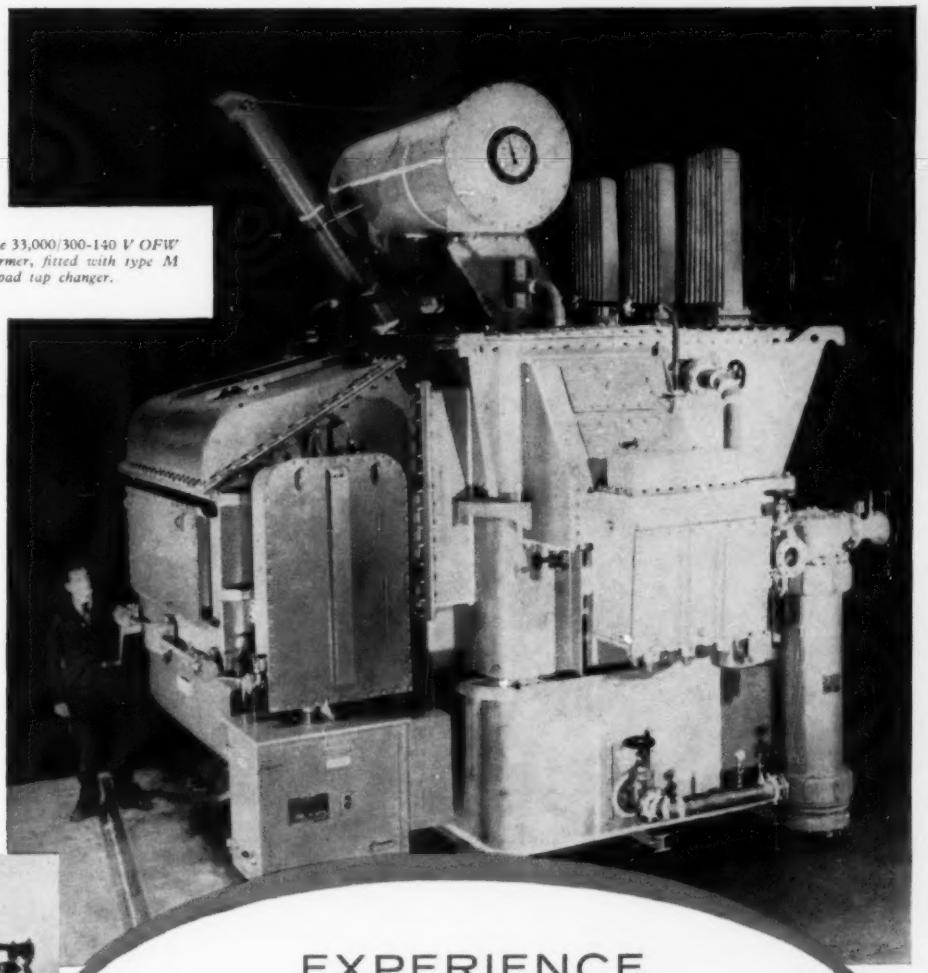
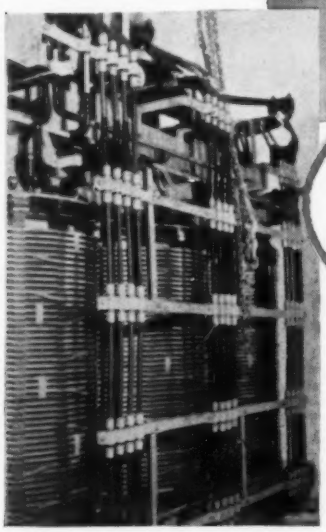


A 10,000 kVA, 3-phase 33,000/300-140 V OFW cooled furnace transformer, fitted with type M resistor transition on-load tap changer.

PHOTO BELOW *by courtesy of N.V. Ned. Kabelfabrieken, Alblasserdam.*



AFTER TEN YEARS' SERVICE

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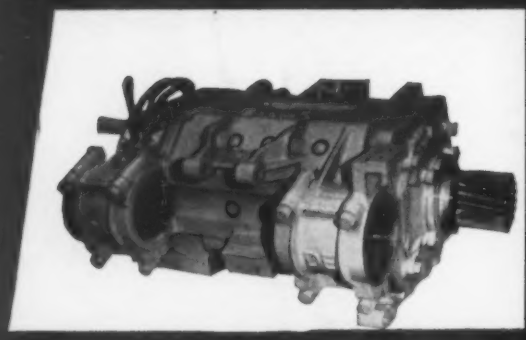

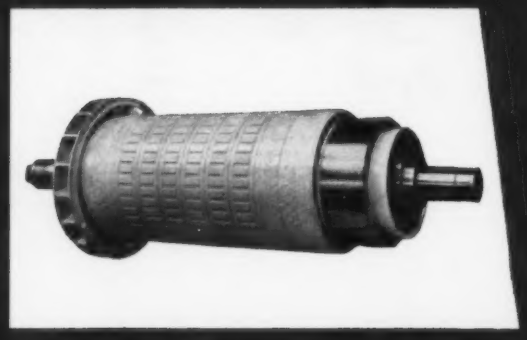

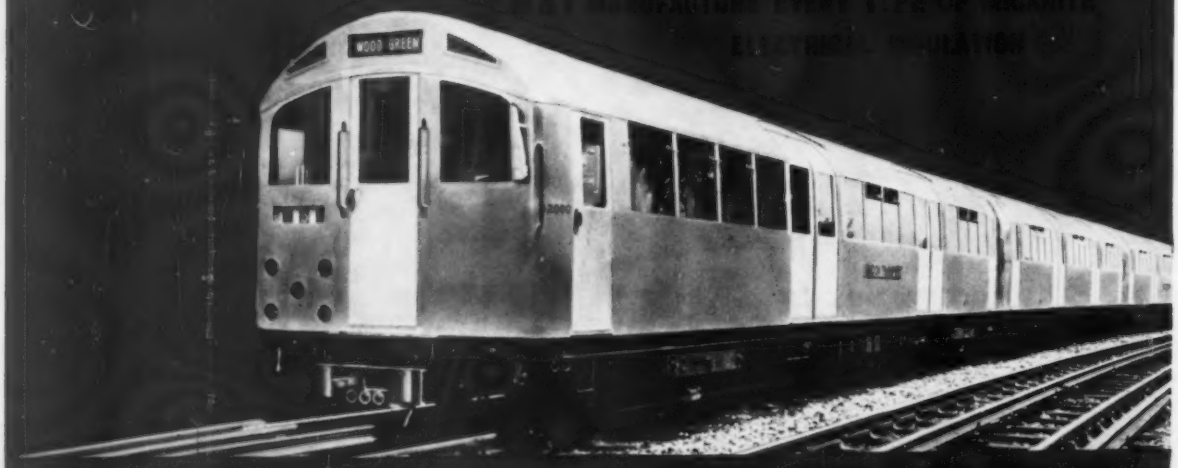

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